Volume 26 OCTOBER, 1942 Number 10

BULLETIN
of the
American Association *of* Petroleum Geologists

CONTENTS

Regional Geology of Dakota Basin *By Norval Ballard* 1557

Interbasin Pennsylvanian Correlations, Illinois and Iowa
By J. M. Weller, H. R. Wanless, L. M. Cline, and D. G. Stookey 1585

Lateral Variation in Chester Sandstones Producing Oil and Gas in Lower Wabash River Area, with Special Reference to New Harmony Field, Illinois and Indiana *By George V. Cohee* 1594

Crocker Flat Landslide Area, Temblor Range, California
By Russell R. Simonson and Max L. Krueger 1608

Payton Pool, Pecos and Ward Counties, Texas *By Richard E. Gile* 1632

Amoura Shale, Costa Rica *By Paul P. Goudkoff and William W. Porter II* 1647

Preparation of Lantern-Slide Copy *By Carl A. Moore* 1656

GEOLOGICAL NOTES

Late Paleozoic Age of Morehouse Formation of Northeastern Louisiana
By Ralph W. Imlay and J. S. Williams 1672

REVIEWS AND NEW PUBLICATIONS

Recent Publications 1674

THE ASSOCIATION ROUND TABLE

Membership Applications Approved for Publication 1675

Association Committees 1676

Members of the A.A.P.G. in Military and Government Service *By F. L. Aurin* 1678

AT HOME AND ABROAD

Current News and Personal Items of the Profession 1692

Change in the Applications for Commissions in the Air Corps *By F. L. Aurin* 1695

Important Supplemental Information on Change in Applications for Interpreters of Aerial Photographs and Intelligence Officers in the Air Corps *By F. L. Aurin* 1695

COPYRIGHT, 1942, BY THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

call in G.S.I.
-let's talk things over
We are busy with war work, as are most others. But, concurrently we are engaging in more Seismograph Research than ever before in our history.
Your company can reap the benefit of this program. Neither you nor Uncle Sam can afford dry holes now. Accurate G.S.I. Seismic Surveys reduce dry hole possibilities to a minimum.
Call in G.S.I., let's talk it over—together we may find a way to serve you and save for you.

GEOPHYSICAL SERVICE INC.

EUGENE McDERMOTT, President

G S I

SEISMOGRAPH SURVEYS

BRANCH OFFICE: HOUSTON, TEXAS

DALLAS, TEXAS

BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

OFFICE OF PUBLICATION, 708 WRIGHT BUILDING, TULSA, OKLAHOMA

WALTER A. VER WIEBE, *Editor*

GEOLOGICAL DEPARTMENT, UNIVERSITY OF WICHITA, WICHITA, KANSAS

ASSOCIATE EDITORS

GENERAL	K. C. HEALD, Gulf Oil Corporation, Box 1166, Pittsburgh, Pa. HUGH D. MISER, U. S. Geological Survey, Washington, D. C. THERON WASSON, Pure Oil Company, 35 E. Wacker Drive, Chicago, Ill.
APPALACHIANS	
North	JOHN R. REEVES, Penn-York Natural Gas Corporation, Buffalo, N. Y.
South	WILLIAM O. ZIEBOLD, Spartan Gas Company, Charleston, W. Va.
NORTH CENTRAL STATES	R. B. NEWCOMBE, 1806 Pleasant Ave., Highland Park, Ill.
KANSAS	ANTHONY FOLGER, Gulf Oil Corporation, Wichita, Kan.
OKLAHOMA	
Western	ROBERT H. DOTT, Oklahoma Geological Survey, Norman, Okla.
Eastern	SHERWOOD BUCKSTAFF, Shell Oil Company, Inc., Box 1191, Tulsa, Okla.
TEXAS	
North and Central	J. B. LOVEJOY, Gulf Oil Corporation, Fort Worth, Tex.
Northeastern	C. I. ALEXANDER, Magnolia Petroleum Company, Tyler, Tex.
San Antonio	JOHN R. SANDIDGE, Magnolia Petroleum Company, San Antonio, Tex.
Permian Basin	E. RUSSELL LLOYD, Box 1026, Midland, Tex.
GULF COAST	SIDNEY A. JUDSON, Texas Gulf Producing Company, Houston, Tex. MARCUS A. HANNA, Gulf Oil Corporation, Houston, Tex.
ARKANSAS AND NORTH LOUISIANA	ROY T. HAZZARD, Gulf Refining Company of Louisiana, Shreveport, La.
ROCKY MOUNTAINS	A. E. BRAINERD, Continental Oil Company, Denver, Colo.
CALIFORNIA	W. S. W. KEW, Standard Oil Company, Los Angeles, Calif. W. D. KLEINPELL, Box 1131, Bakersfield, Calif.
FOREIGN	
Canada	THEODORE A. LINK, Imperial Oil, Ltd., Calgary, Alberta
South America	HOLLIS D. HEDBERG, Mene Grande Oil Co., Apt. 45, Barcelona, Venezuela

THE BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS is published by the Association on the 15th of each month. Editorial and publication office, 708 Wright Building, Tulsa, Oklahoma, Post Office Box 979.

THE SUBSCRIPTION PRICE to non-members of the Association is $15.00 per year (separate numbers, $1.50) prepaid to addresses in the United States. For addresses outside the United States, an additional charge of $0.40 is made on each subscription to cover extra wrapping and handling.

British agent: Thomas Murby & Co., 40 Museum Street, London, W. C. I.

CLAIMS FOR NON-RECEIPT of preceding numbers of THE BULLETIN must be sent Association headquarters within three months of the date of publication in order to be filled gratis.

BACK NUMBERS OF THE BULLETIN, as available, can be ordered from Association headquarters. Cloth-bound Vols. 11 (1927) to 15 (1931), each $6.00; Vols. 22 (1938) to 25 (1941), each $17.00. Other volumes, many separate numbers, and a few nearly complete sets are available. Descriptive price list sent on request. Special prices to members and associates. Discounts to libraries. *Geology of Natural Gas* (1935), $6.00 ($4.50 to members and associates). *Geology of Tampico Region, Mexico* (1936), $4.50 ($3.50 to members and associates). *Gulf Coast Oil Fields* (1936), $4.00 ($3.00 to members and associates). *Miocene Stratigraphy of California* (1938), $5.00 ($4.50 to members and associates). *Possible Future Oil Provinces of the United States and Canada* (1941), $1.50 ($1.00 to members and associates). *Stratigraphic Type Oil Fields* (1941), $5.50 ($4.50 to members and associates). *Origin of Oil* (1942) $1.00. *Source Beds of Petroleum* (1942), $4.50 ($3.50 to members and associates). *Permian of West Texas and Southeastern New Mexico* (1942), $2.00 ($1.50 to members and associates). *Petroleum-Discovery Methods* (1942), $1.00.

THE BULLETIN gives senior authors 35 reprints of major papers. Additional reprints, in limited numbers, and for private distribution, are furnished at cost, if orders accompany corrected galley proof.

Association Headquarters—708 Wright Building, 115 and 117 West Third Street, Tulsa, Oklahoma.

Communications about the Bulletin, manuscripts, editorial matters, subscriptions, special rates to public and university libraries, publications, membership, change of address, advertising rates, and other Association business should be addressed to

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

BOX 979
TULSA, OKLAHOMA

Entered as second-class matter at the Post Office at Tulsa, Oklahoma, and at the Post Office at Menasha, Wisconsin, under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized March 9, 1923.

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

Organized at Tulsa, Oklahoma, February 10, 1917, as the Southwestern Association of Petroleum Geologists. Present name adopted, February 16, 1918. Incorporated in Colorado, April 23, 1924. Domesticated in Oklahoma, February 9, 1925.

OFFICERS FOR THE YEAR ENDING APRIL, 1943

FRITZ L. AURIN, *President*, Fort Worth, Texas
EDMOND O. MARKHAM, *Secretary-Treasurer*, Tulsa, Okla.
PAUL WEAVER, *Vice-President*, Houston, Texas
WALTER A. VER WIEBE, *Editor*, Wichita, Kansas

The foregoing officers, together with the *Past-President*, EDGAR W. OWEN, San Antonio, Texas, constitute the Executive Committee.

DISTRICT REPRESENTATIVES

(Representatives' terms expire immediately after annual meetings of the years shown in parentheses)

Amarillo: Archie R. Kautz (44), Amarillo, Tex.
Appalachian: J. R. Lockett (43), Columbus, Ohio
Canada: Theodore A. Link (43), Calgary, Canada
Capital: L. W. Stephenson (44), Washington, D. C.
Dallas: Dilworth S. Hager (44), Dallas, Tex.
East Oklahoma: T. C. Hiestand (44), Bartlesville; L. L. Foley (43), Louis Roark (43), Tulsa
Fort Worth: Charles E. Yager (43), Fort Worth, Tex.
Great Lakes: Darsie A. Green (43), Olney, Ill.; L. E. Workman (43), Urbana, Ill.
Houston: Marcus A. Hanna (43), Phil F. Martyn (43), R. C. Bowles (44), Leslie Bowling (44), Houston, Tex.
New Mexico: Neil H. Wills (43), Carlsbad, N. Mex.
New York: Fred B. Ely (43), New York City
Pacific Coast: Albert Gregersen (43), W. D. Kleinpell (43) Karl Arleth (44), Max L. Krueger (44), Los Angeles, Calif.
Rocky Mountains: C. S. Lavington (43), Denver, Colo.
Shreveport: C. C. Clark (43), Shreveport, La.
South America: Frank B. Notestein (43), Caracas, Venezuela
Southeast Gulf: Urban B. Hughes (43), Jackson, Miss.
Southern Louisiana: Dean F. Metts (43), Lake Charles
So. Permian Basin: C. D. Vertrees (43), Midland, Tex.
South Texas: Robert N. Kolm (44), San Antonio; L.W. Storm (43), Corpus Christi, Tex.
Tyler: George W. Pirtle (43), Tyler, Tex.
West Oklahoma: D. A. McGee (43), Oklahoma City, Okla.
Wichita: John L. Garlough (43), Wichita, Kan.
Wichita Falls: W. C. Bean (44), Wichita Falls, Tex.

DIVISION REPRESENTATIVES

Paleontology and Mineralogy

Herschel L. Driver (43), Los Angeles, California
Henryk B. Stenzel (43), Austin, Texas

PACIFIC SECTION (Chartered, March, 1925)

E. J. BARTOSH, *President*, Bankline Oil Company, Los Angeles, California
E. R. ATWILL, *Secretary-Treasurer*, Union Oil Company, Los Angeles, California
Membership restricted to members of the Association in good standing, residing in Pacific Coast states. Dues: $1.50 per year

SOUTH TEXAS SECTION (Chartered, April, 1929)

W. W. HAMMOND, *President*, Magnolia Petroleum Co., 1704 Alamo National Building, San Antonio, Texas
WM. H. CURRY, *Secretary-Treasurer*, Wellington Oil Co., 1108 South Texas Bank Bldg., San Antonio, Texas
Membership limited to persons eligible to Association membership. Dues: $2.50. Annual meeting in October.

MARACAIBO SECTION (Chartered, April, 1930)

JOHN G. DOUGLAS, *President*, Mene Grande Oil Company, Apartado 234, Maracaibo, Venezuela

DIVISION OF PALEONTOLOGY AND MINERALOGY
SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

(Organized, March, 1927; affiliated, March, 1928; chartered, technical division, April, 1930)
HERSCHEL L. DRIVER, *President*, Los Angeles, California
HENRYK B. STENZEL, *Secretary-Treasurer*, Bureau of Economic Geology, Austin, Texas
SEND DUES, SUBSCRIPTIONS, AND ORDERS FOR BACK NUMBERS TO BOX 979, TULSA, OKLAHOMA.

The Society and the Paleontological Society jointly issue six times a year the *Journal of Paleontology*, J. Marvin Weller, Illinois Geological Survey, Urbana, Illinois, and C. Wythe Cooke, U. S. Geological Survey, Washington, D. C., editors: subscription, $6.00. The *Journal of Sedimentary Petrology*, W. H. Twenhofel, editor, University of Wisconsin, Madison, Wisconsin, is issued three times a year: subscription, $3.00. Single copies, *Journal of Paleontology*, $2.00; *Journal of Sedimentary Petrology*. $1.50. Society dues: with *Jour. Pal.*, $5.00; with *Jour. Sed. Petrology*, $3.00; with both, $8.00 per year.

AFFILIATED SOCIETIES

(Dates of affiliation in parentheses)

Alberta Society of Petroleum Geologists, Calgary, Alberta, Canada (31). D. B. Layer, Secy., McColl-Frontenac Oil Co., Ltd.
Appalachian Geological Society, Charleston, W. Virginia (31). Robert S. Hyde, Secy., West Virginia Gas Corp., Box 404
Ardmore Geological Society, Ardmore, Oklahoma (36). Frank Neighbor, Secy., Sinclair Prairie Oil Company
Dallas Petroleum Geologists, Dallas, Texas (35). Barney Fisher, Secy., Coronado Corporation
East Texas Geological Society, Tyler, Texas (32). Laurence Brundall, Secy., Shell Oil Company, Inc., Box 2037, Tyler
Fort Worth Geological Society, Fort Worth, Texas (31). Richard H. Schweers, Secy., The Texas Company
Houston Geological Society, Houston, Texas (32). W. Z. Burkhead, Secy., Union Oil Co. of California, 1134 Commerce Bldg.
Illinois Geological Society (39). V. C. Scott, Secy., The Texas Company, Box 476, Mattoon
Indiana-Kentucky Geological Society (38). Edward J. Combs, Secy., Sun Oil Company, Evansville, Indiana
Kansas Geological Society, Wichita, Kansas (31). Z. E. Stucky, Secy., Cities Service Oil Company
Michigan Geological Society (37). Edward J. Baltrusaitis, Secy., Box 811, Saginaw
Mississippi Geological Society, Jackson, Miss. (41). A. A. Holston, Secy., Stanolind Oil and Gas Company, Box 689
North Texas Geological Society, Wichita Falls, Texas (38). Dolphe E. Simic, Secy., Cities Service Oil Company
Oklahoma City Geological Society, Oklahoma City, Okla. (31). H. T. Brown, Secy., Cities Service Oil Company, Box 4577
Panhandle Geological Society, Amarillo, Texas (32). Fred A. Devin, Secy., The Pure Oil Company, Box 2127
Shawnee Geological Society, Shawnee, Oklahoma (31). Martyna Garrison, Secy., Amerada Petroleum Corporation
Shreveport Geological Society, Shreveport, Louisiana (32). Van D. Robinson, Secy., Atlantic Refg. Co., 1001 City Bank Bldg.
Society of Exploration Geophysicists, Houston, Tex. (32). T. I. Harkins, Secy., Independent Exploration Company
South Louisiana Geological Society, Lake Charles, La. (37). Roy A. Payne, Secy., Gulf Refining Company
Tulsa Geological Society, Tulsa, Oklahoma (31). Louis H. Desjardins, Secy., Aero-Geologist, 739 Kennedy Bldg.
West Texas Geological Society, Midland, Texas (38). William M. Osborn, Secy., consulting, Box 707

FOR SUPERIOR GEOPHYSICAL RECORDINGS

HALOID RECORD

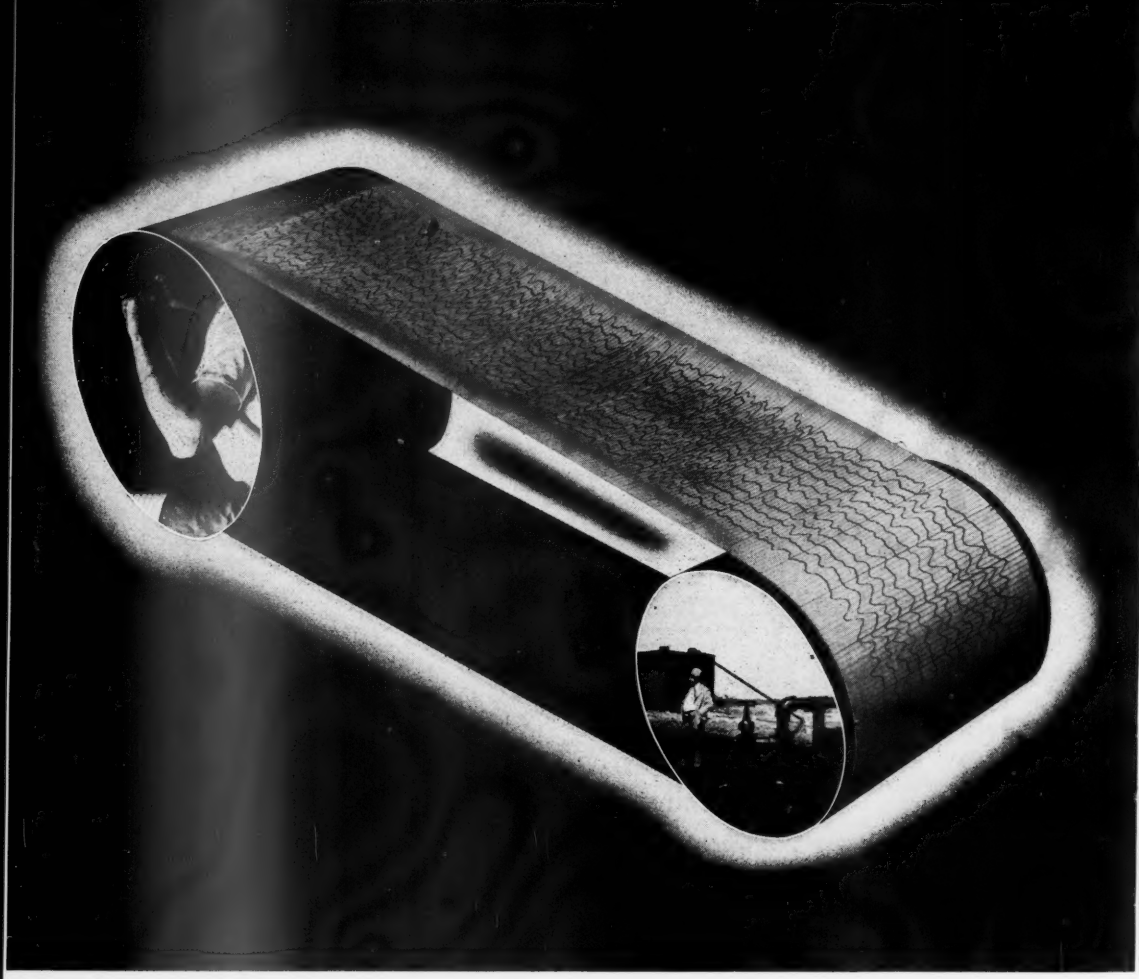
SEISMOGRAPH RECORDING PAPER

• Under every conceivable condition of field and laboratory . . . seismograph records must be consistently sharp, clear and legible. That's why . . . *when judged by actual performance* . . . Haloid Record is the favorite recording paper of critical geophysicists. For, Haloid Record successfully combines abuse-resistance with photographic excellence.

Reason enough why geophysicists specify Haloid Record for its vivid contrast . . . sharp legibility . . . exceptional latitude . . . rapid free development and other advantageous features.

THE HALOID COMPANY • 712 Haloid St. • Rochester, N.Y.

Seismology . . the **DRIVING FORCE** *behind* **NEW DISCOVERIES**



BUILD up your "back-log" of production . . . oil to keep 'em flying in the future . . . and build it on accurate sub-surface data compiled by General.

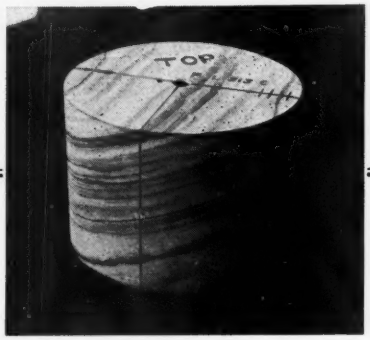
General

GEOPHYSICAL COMPANY HOUSTON

Sperry-Sun's
CORE
ORIENTATION
SERVICE

RAPID, INEXPENSIVE
VERY ACCURATE

This service is of immense value in wildcatting, inasmuch as it may indicate the direction of the strata encountered. It is bound to save time and money. It doesn't interfere with the progress of drilling as the direction and angle of dip of core samples with visible indication of a bedding plane are determined in our laboratory. We can orient cores as small as 1" diameter and 2½" in length. Cores hand-picked out of core trays chosen for bedding planes and sizes, properly marked top and bottom, can be shipped to our laboratory from any distance. Write for Price List.



SPERRY-SUN WELL SURVEYING CO.
Core Orientation Laboratory, 549 E. Bixby Road, Long Beach, Calif.

Experience - The Great Teacher!

65,000 ELECTRICAL LOGS IN 32 STATES OF THE U·S·A

Schlumberger Well Surveying Corporation

HOUSTON, TEXAS

Bulletin Advertisers

Atlas Powder Company .....

Baker Oil Tools, Inc. .....
Baroid Sales Department xviii
Barret, William M., Inc. xxvi
Bausch and Lomb .....

Dowell Incorporated viii

Economic Geology Publishing Company ..xvii

Federal Electric Company, Inc. xxiv
First Natl. Bank and Trust Co. of Tulsa .xviii

General Geophysical Company iv
Geophysical Service, Inc. .....Cover ii
Geotechnical Corporation xviii
Gravity Meter Exploration Company .....
Gulf Publishing Company xx

Haloid Company iii
Hercules Powder Company, Inc. .....
Hughes Tool Company, Inc. .....Cover iv

Illinois Powder Company .....
Independent Exploration Company xxi

Journal of Geology xvii
Journal of Paleontology .....

Journal of Sedimentary Petrology .....

Lane-Wells Company xxiii
Lufkin Rule Company .....

National Geophysical Company xxviii

Petty Geophysical Engineering Company ....

Robert H. Ray, Inc. .....
Rogers-Ray, Inc. .....
Reed Roller Bit Company .....Cover iii
Rouse Exploration Drilling Company .....

Schlumberger Well Surveying Corporation ..vi
Seismic Explorations, Inc. xxv
Seismograph Service Corporation .....
Society of Exploration Geophysicists .....
Spencer Lens Company xix
Sperry-Sun Well Surveying Company v

Tobin Aerial Surveys .....
Triangle Blue Print and Supply Company ....

United Geophysical Company xxii

Western Geophysical Company xxvii

PROFESSIONAL CARDS

California ix
Colorado ix
Illinois ix
Indiana x
Iowa x
Kansas x
Louisiana x
New York x
Ohio x
Oklahoma xi
Pennsylvania xi
Texas .....xi, xii, xiii
West Virginia xiii
Wyoming xiii

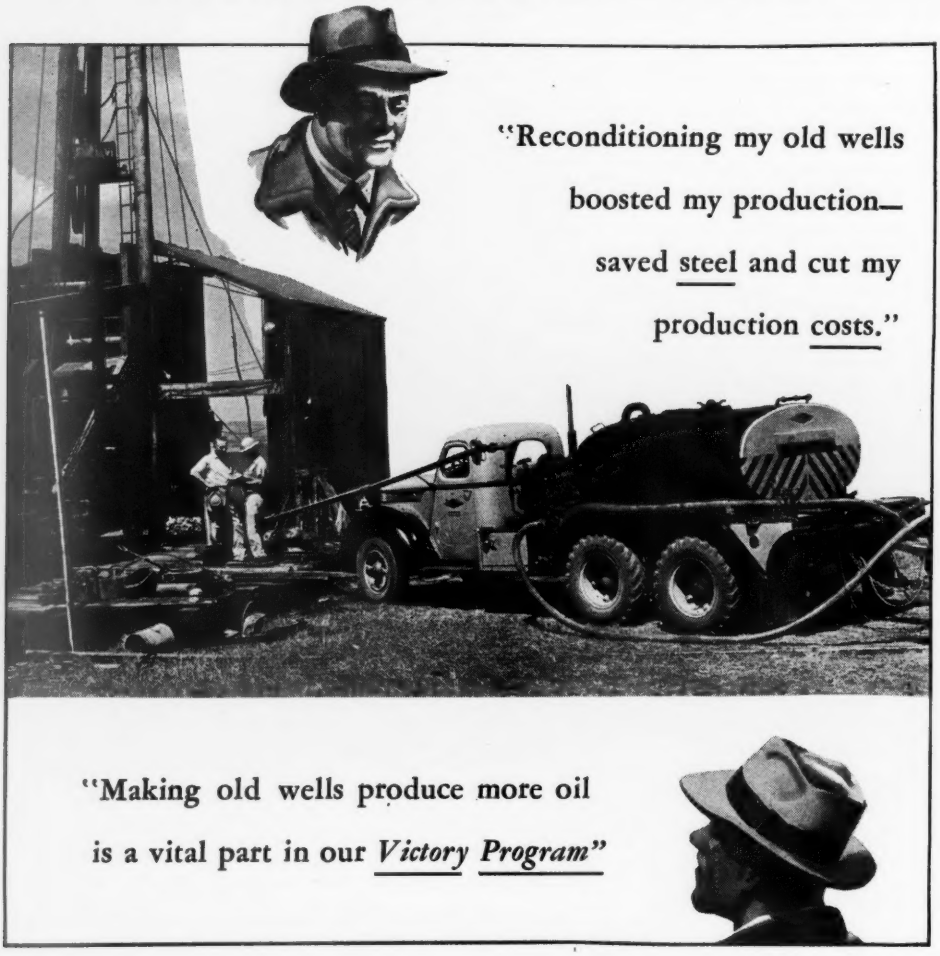
GEOLOGICAL AND GEOPHYSICAL SOCIETIES

Appalachian xvi
Ardmore xv
Dallas xv
East Texas xvi
Exploration Geophysicists .xvi
Fort Worth xvi
Houston xvi
Illinois xiv
Indiana-Kentucky xiv
Kansas xiv
Michigan xv
Mississippi xv
North Texas xvi
Oklahoma City xv
Rocky Mountain xiv
Shawnee xv
Shreveport xiv
South Louisiana xiv
South Texas xvi
Stratigraphic xv
Tulsa xv
West Texas xvi

Articles for November *Bulletin*

Stratigraphical Analysis and Environmental Reconstruction

By THOMAS G. PAYNE


"Reconditioning my old wells boosted my production— saved steel and cut my production costs."
"Making old wells produce more oil is a vital part in our Victory Program"

OLD WELLS—whether they have declined in production, been deepened or plugged back to a new horizon are usually perfect subjects for Dowell's Reconditioning Service.

Reconditioning protects and lengthens the producing life of old wells. It aids in postponing the time when old wells must be abandoned, thereby helping to maintain the nation's oil reserves with a saving in steel and manpower.

The productivity of any type formation may be improved with this Dowell Service. Permeability is increased by removal of paraffin and scale deposits or treating the formation itself.

All Dowell field men are well qualified to discuss this vital service with you. They have the "know how" experience that has made Dowell Reconditioning so profitable to such a great number of operators.

Look to DOWELL
1932 FOR OIL AND GAS WELL CHEMICAL SERVICE 1942
A DECADE OF SERVICE TO THE OIL AND GAS INDUSTRY

DOWELL INCORPORATED
Executive Office: MIDLAND, MICHIGAN
General Office: KENNEDY BUILDING, TULSA, OKLAHOMA
Subsidiary of The Dow Chemical Company

Volume 26 Number 10

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

OCTOBER, 1942

REGIONAL GEOLOGY OF DAKOTA BASIN[1]

NORVAL BALLARD[2]
Oklahoma City, Oklahoma

ABSTRACT

This article contains a discussion of the stratigraphy of the surface and subsurface formations found in North Dakota and South Dakota. There is a structure map contoured on the top of the Dakota sandstone. The periods of tilting and folding are discussed, with the evidence for these structural deformations. Three cross sections further explain the structure and geologic history. Paleogeologic maps for the pre-Cretaceous and the pre-Pennsylvanian surfaces are shown. Two isopach maps are included to show that in pre-Pennsylvanian time there was an anticline with 200–300 feet of closure in the Black Hills area. The possible oil- and gas-producing zones of North and South Dakota are discussed and compared with the sands producing oil or gas in the surrounding area.

INTRODUCTION

This article is primarily a progress report concerned with the regional geology of North Dakota and South Dakota. However, the writer found that in order to understand the geology of this region, it is necessary to study, compare, and correlate the formations in the adjoining states on the east, south, and west. During the course of the investigation, outcrops were examined along the Laramie Range, on the Hartville uplift, and in the Black Hills. Drillers' logs of approximately 300 tests were plotted and well cuttings from 75 deep holes were examined.

GENERAL FEATURES

Figure 1 is a map showing the areal geology of the northern Great Plains. It has been adapted from the areal map of the United States prepared by the United States Geological Survey. The areal geology shows the chief structural features of the region: (1) on the east side, the west-dipping high pre-Cambrian area of the Archean shield and the Sioux uplift; (2) the Black Hills, and the Cedar Creek or Baker-Glendive anticline which forms the west flank of the (3)

[1] Read before the Association at Denver, April 24, 1942. Manuscript received, May 30, 1942.

[2] Consulting geologist, 1105 Northeast Twentieth Street. The writer sincerely appreciates the whole-hearted assistance of Frank C. Foley, formerly State geologist of North Dakota; E. P. Rothrock, director of the South Dakota Geological Survey; and H. D. Thomas, of the University of Wyoming. He is also indebted to many individuals of the geological groups, who by their discussions have aided in the solution of many of the problems. Previous publications have been drawn upon freely.

The writer is indebted to A. I. Levorsen and Fred G. Moser for permission to publish this article and to A. I. Levorsen, Anthony Folger, D. A. McGee, and T. C. Heistand for helpful suggestions about the treatment of the subject.

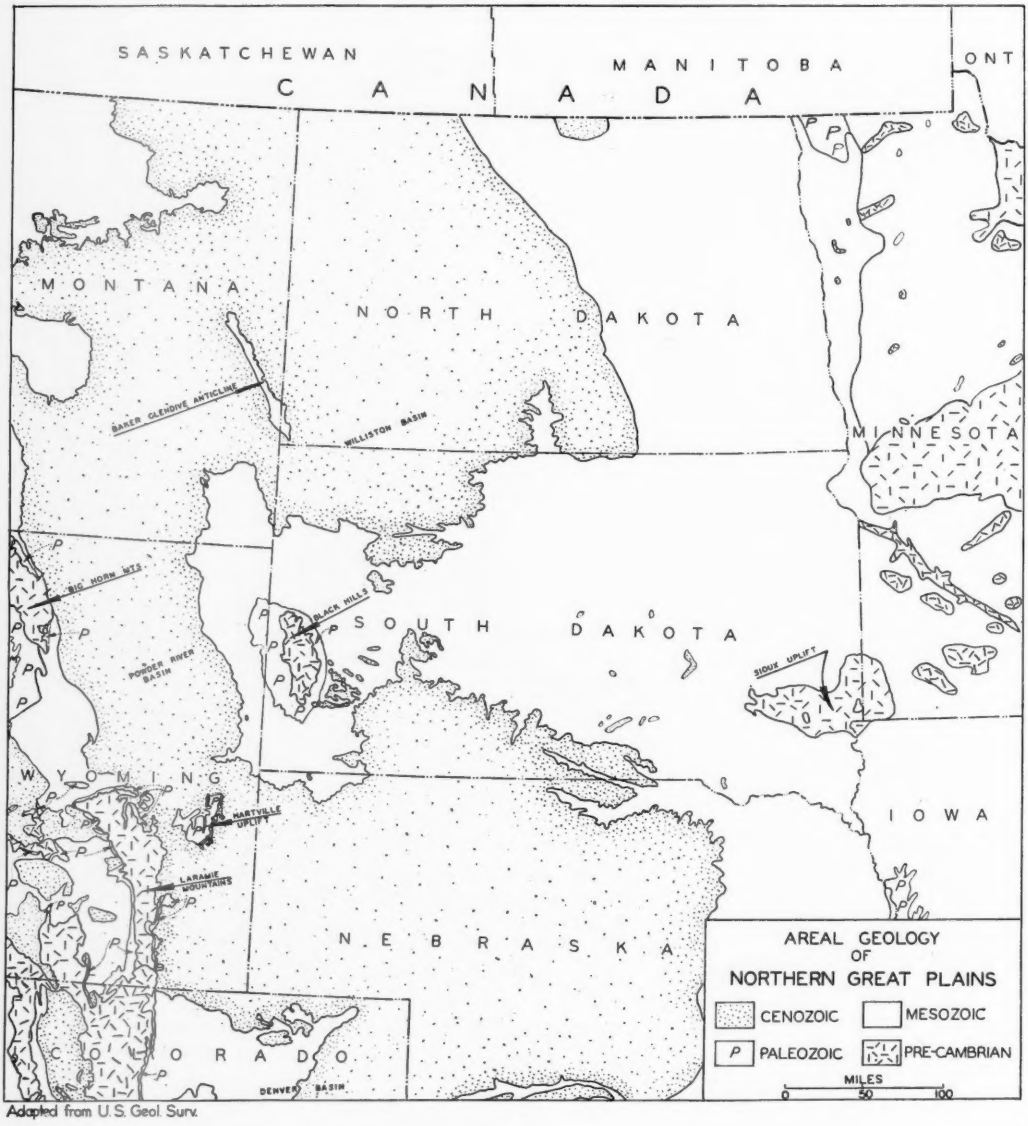


FIG. 1.—Areal geology of Northern Great Plains.

Williston basin; (4) the Laramie Range with its northeast projection known as the Hartville uplift; (5) the Big Horn Mountains which trend northwest from the Laramie Range; and (6) the Powder River Basin which lies between the Big Horn Mountains and the Black Hills.

The sedimentary rocks in this area range in age from Cambrian to Recent and are approximately 16,000 feet thick in the center of the Powder River Basin according to John G. Bartram.[3]

Although there was regional tilting in various directions during the early Paleozoic, the Black Hills were first anticlinally folded in post-Mississippian, pre-Pennsylvanian time with the main orogeny occurring at the end of Upper Cretaceous or in early Eocene time. In the region covered by this article, the last period of folding of which we have any record occurred after the White River beds had been deposited for these strata are gently folded in southwestern South Dakota.

STRATIGRAPHY

QUATERNARY SYSTEM

PLEISTOCENE OR RECENT SERIES

In North Dakota and South Dakota, alluvial deposits of reworked shales, gravels, and sandstones from Pierre, Fox Hills, Lance, and Fort Union beds are present in all of the larger stream valleys and are common in many of the smaller ones. From the evidence observed, the writer is inclined to consider all or at least part of these deposits as the western and southern equivalents of the northern boulder clays of glacial origin. The thickness of the deposits varies from a feather edge to 10 feet. In eastern North Dakota in the valley of the Red River, glacial Lake Agassiz deposited silt which reaches a maximum thickness of 100 feet.

PLEISTOCENE SERIES

Glacial deposits extend southward from the Canadian border into Nebraska and westward from Minnesota to a north-south line slightly west of the Missouri River Valley. The glacial drift contains gray to buff boulder clays, gravels, and coarse-grained unconsolidated sands, which thin west and south from a maximum of 500 feet near the North Dakota-Manitoba border.

TERTIARY SYSTEM

OLIGOCENE SERIES

WHITE RIVER GROUP

The White River group, exposed in the badlands of southwestern South Dakota, is composed of volcanic ash, a pinkish gray, sandy, massive clay, intercalated with thin beds of gray to pink, fine to coarse, unconsolidated, calcareous sands. Toward the base of the group the amount of sand gradually increases until the clays disappear. At most localities there is a basal conglomerate. Rapid lat-

[3] *Guide Book, 14th Annual Field Conference*, Kansas Geol. Soc. (1940), p. 113.

eral gradations take place throughout the beds of the White River group. The thickness of this group varies from a few inches to approximately 400 feet.

EOCENE SERIES

Fort Union formation.—The Fort Union crops out in South Dakota only as isolated exposures near the northwest boundary of the state. In North Dakota this formation occupies most of the western half of the state. Here it may be divided into upper and lower members. The former contains 450 feet of gray sandy clay and gray to buff, lignitic, fine- to medium-grained sand which is finer-grained, more lignitic, and less cross-bedded than the Lance sandstone. The lower member of the Fort Union contains more gray, sandy clay than the upper member. The Fort Union varies from a feather edge in South Dakota and central North Dakota to more than 1,200 feet in western North Dakota. It is probably conformable with the underlying Lance in the Williston basin.

PALEOCENE SERIES

Lance formation.—The eastern edge of the Lance formation is found in Kidder, Logan, and McIntosh counties, North Dakota. Southwest from these counties it extends as a broad band 50–100 miles wide into southwestern Harding County, South Dakota. The Lance also may be divided into upper and lower members. The upper has two phases, the marine or Cannonball phase and the Ludlow or lignitic phase. The Cannonball contains gray, massive, poorly consolidated sandstone with intercalated gray sandy shales. The Ludlow, which is very similar to the Hell Creek or lower Lance, contains gray to buff, very lignitic, unconsolidated sand and gray to brown, lignitic sandy shales. The shales contain many beds of brown, slightly weathered limonite pebbles. These pebbles are not nearly so weathered as those contained in the underlying Fox Hills. At the base of the Lance there is commonly buff, friable, fine- to coarse-grained, cross-bedded sandstone which locally contains small pebbles from the underlying Fox Hills. There is some evidence that the basal Lance sand lies on successively older Fox Hills in an easterly direction. The Cannonball-Ludlow varies from a few inches to 300 feet and the Hell Creek attains a maximum thickness of 600 feet.

CRETACEOUS SYSTEM

Fox Hills formation.—Southwest from Kidder County, North Dakota, the Fox Hills crops out as a band 10–40 miles wide, crossing the state line into north-central Corson County, South Dakota, and extending westward into Harding County. It is believed that strata of the Fox Hills will be found under cover in most of the west half of North Dakota. The upper half of the Fox Hills contains shaly, friable, gray sandstone, which grades downward into gray sandy shales containing several zones of ironstone concretions, one of which is very fossiliferous. At the top of a complete section of Fox Hills is gray to buff, concretionary sandstone containing many shells of *Ostrea glabra*. The contact between the Fox

Hills and the underlying Pierre is gradational. In the Dakotas, a complete section of Fox Hills contains approximately 350 feet.

Pierre shale.—The Pierre shale forms the surface rock over most of the eastern half of North Dakota and South Dakota but its outcrop narrows toward the Black Hills due to the Tertiary overlap. Downdip from the outcrop it is everywhere found in the subsurface of both the Dakotas. The Pierre is dark to gray, uniform gumbo shale with several calcareous zones in the basal beds. There are also irregular occurrences of dark reddish gray, manganiferous, ironstone concretions which vary from a few inches to more than 2 feet in diameter. The contact with the underlying Niobrara is gradational. The Pierre thickens from 1,200 feet near the Black Hills to more than 2,000 feet in western North Dakota. The Shannon sandstone, which produces oil in eastern Wyoming, occurs in the Pierre. The Judith River and Eagle gas-producing sands on the Baker-Glendive anticline of southeastern Montana, occur in a western equivalent of the Pierre shale.

Niobrara formation.—The Niobrara crops out as a narrow band around the Black Hills and the Sioux uplift but most of its outcrop in eastern North Dakota is obscured by the overlap of the Quaternary lake silt. Downdip from the outcrop it is everywhere present in the subsurface. The Niobrara contains 200–325 feet of impure chalk which grades into dark gray shale speckled with white chalk inclusions. The Niobrara is conformable with the adjacent formations.

BENTON GROUP

In descending order, the Benton group is made up of the Carlile shale, Greenhorn limestone, and Graneros shale. The strata of the Benton group crop out on all flanks of the Black Hills and at scattered points on the south and west sides of the Sioux uplift but are found only in the subsurface elsewhere in the Dakotas. The Carlile is gray, fine-grained shale which locally contains 5–15 feet of shaly sandstone at the top. It is not as dark colored as the overlying Niobrara or the underlying Graneros. The thickness of the Carlile varies from 750 feet in the Black Hills to 100 feet in eastern South Dakota. The Greenhorn contains alternating beds of dark gray, calcareous shale and thin beds of aragonitic, fossiliferous limestone. The average thickness is 60 feet. The Graneros is dark gray, bentonitic clay shale which locally contains gray, fine-grained shaly sandstone in the lower part. This sand which is not developed very far east of the Wyoming line is the Muddy or Newcastle sandstone. The thickness of the Graneros varies from 1,100 feet in the Black Hills to 90 feet in Clay County in the southeast corner of South Dakota. This thinning of the Graneros is probably due to the Dakota sandstone transgressing upward across the basal shale beds of the Graneros in an easterly direction, thereby making the top beds of the Dakota younger on the east flank of the basin than they are farther west. The Benton group is conformable with the underlying Dakota group. The Wall Creek and Newcastle or Muddy sands, which are oil-bearing in eastern Wyoming, are found in the Benton group.

DAKOTA GROUP[4]

The strata of the Dakota group crop out as hogbacks completely surrounding the Black Hills and are found throughout the Dakotas in the subsurface. The upper member of this group is gray, fine- to coarse-grained, angular, well cemented to porous sandstone with thin interbedded shale streaks. The middle or Fuson shale member is gray, greenish, or maroon clay shale, locally containing coaly beds and a thin limestone near the base. The lower or Lakota sandstone member is gray to buff, coarse-grained to conglomeratic, cross-bedded sandstone containing thin streaks of shale similar to that of the Fuson. Although the Dakota is Upper Cretaceous and the Fuson-Lakota beds are Lower Cretaceous in age there is no evidence of great unconformity between the two. On the other hand there is generally a conglomerate marking the unconformity at the base of the Lakota. The thickness of the Dakota group varies from 725 feet in Fuson Canyon in the Black Hills to a few inches in parts of eastern South Dakota near the Sioux uplift. Sands of the Dakota group produce gas in parts of North Dakota and South Dakota and oil in eastern Wyoming.

JURASSIC SYSTEM

The Canadian facies of the Jurassic is found in the subsurface of northeastern North Dakota. It contains gray marine shales as well as red to maroon shale intercalated in a few places with streaks of anhydrite and sandy shale. These shales, approximately 200 feet thick, overlap beds ranging in age down to and including the Devonian. Although the relation between these beds and the Black Hills Jurassic is not clear, the meager evidence available suggests that they are the eastern equivalents of the Sundance strata.

Morrison shale.—The Morrison crops out high on the flanks of the Black Hills and probably exists in the subsurface in the western third of the Dakotas. It contains greenish gray, pure to sandy, clay shales which locally contain maroon beds. In places, in the lower part of the Morrison, there are thin beds of light gray lithographic limestone. On the south, southeast, and southwest sides of the Black Hills, the lower half of these sandy clays grades laterally into massive, white, fine-grained sandstone which Darton called Unkpapa. The thicknesses of the Morrison and Unkpapa are complementary. Nevertheless, the thickness is very erratic because of the overlying unconformity. Westward from the east side of the Williston basin, the Morrison thickens from a few inches to 220 feet near Piedmont in the Black Hills.

Sundance formation.—The Sundance crops out on the inner margin of the Morrison in the Black Hills. The writer thinks that the Sundance sands and shales will probably be found under the western third of South Dakota and under

[4] Willis T. Lee in *U. S. Geol. Survey Prof. Paper 149* considers the Muddy sand of the Big Horn Basin, Wyoming, and its equivalents in the other parts of Wyoming and Colorado, to be the "Upper sand" member of the Dakota group rather than a sand member in the lower Colorado shale. The Muddy sand has graded laterally into shale over much of North and South Dakota. Since it is impossible to pick the top of the Muddy sand, the writer has restricted the Dakota group to the Dakota sandstone, Fuson shale and Lakota sandstone.

at least the western third of North Dakota. The Sundance shales are very similar to those of the Morrison from which they differ in being darker green. The Sundance contains very fine-grained, glauconitic, angular, porous to well cemented, gray to pink sandstone which becomes more shaly northeast. There is 150–200 feet of brownish red shale containing two or three light gray to pink, finely crystalline limestones in the basin north of the Black Hills. These beds are possibly correlative with the Twin Creek of Wyoming. The Jurassic, probably Sundance, lies on the beveled edges of strata ranging from Triassic to Devonian in age in the east half of North Dakota. The thickness varies from a few inches along the eastern margin of this overlap to 735 feet in the basin north of the Black Hills. The Sundance sands produce oil in the Lance Creek field of eastern Wyoming.

TRIASSIC SYSTEM

Spearfish formation.—The outcrop of the Spearfish beds forms the Red Valley which completely surrounds the Black Hills. These strata probably underlie the western third of North and South Dakota. The Spearfish contains rusty to red, fine-grained, argillaceous sands and pure to sandy shales which south and east of the Black Hills are intercalated with two or three beds of anhydrite. The number and thicknesses of the sands increase northwest of the Black Hills. In the lower part of the Spearfish is a red, very fine-grained, shaly sandstone or sandy shale which some geologists place in the Permian rather than the Triassic. The Spearfish is conformable with the underlying Minnekahta limestone but thins eastward due to pre-Sundance erosion. The maximum thickness known to the writer occurs in the north part of the Black Hills where 830 feet of these strata were penetrated in the Wytex Oil Company's Hamilton No. 1, Sec. 32, T. 8 N., R. 1 E., Butte County, South Dakota.

PERMIAN SYSTEM

Minnekahta limestone.—The outcrop of the Minnekahta limestone rims the Black Hills and the writer believes that it occurs beneath the surface in the west half of North Dakota and probably the west third of South Dakota. The Minnekahta contains 40–60 feet of purplish gray, very finely crystalline limestone or dolomite which in many places gives off a bituminous odor when struck with a hammer.

Opeche formation.—In the Black Hills, the Opeche crops out in the shale valley beneath the Minnekahta hogback. In the subsurface it has been found as far east as Oliver County, North Dakota, and Stanley County, South Dakota. This formation contains 60–160 feet of predominantly dark purplish red shale with minor anhydrite and red, shaly sandstone, or siltstone. The Opeche-Minnelusa contact appears to be gradational.

PERMO-PENNSYLVANIAN SYSTEM

Minnelusa formation.—The Minnelusa crops out on the outer margin of the high Mississippian limestone plateau of the Black Hills. It is the writer's opinion

that the stratigraphic test of the Carter Oil Company in Sec. 34, T. 118 N., R. 78 W., Potter County, South Dakota, penetrated porous limestone and dolomite of the Minnelusa from 2,227 to 2,322 feet. From this depth to 2,373 feet, the formation contained red or green sandy shale and thin sandstones. The test being drilled by the same company in Sec. 18, T. 141 N., R. 8 W., Oliver County, North Dakota, penetrated approximately 625 feet of Minnelusa, of which 180 feet was porous, medium to coarse sand. So variable is the Minnelusa that bed-for-bed correlations can not be made in an area as restricted as the Lance Creek oil field. The Minnelusa contains gray to red, fine to coarse sandstone; gray to pink, crystalline to dense, slightly cherty limestone and dolomite; anhydrite; and black coaly to red shale. The upper part contains more sand and the lower two-thirds is predominantly dolomite and anhydrite with a basal series of red shale and sand. The Minnelusa contains the greatest percentage of sandstone southwest of the Black Hills. These sandstones seem to grade northward into red sandy shales and anhydrite so that in The California Company test in Sec. 3, T. 154 N., R. 96 W., practically all of the Minnelusa is represented by non-porous red sandy shale and evaporites. There is a widespread unconformity at the base of the Minnelusa. The average thickness of this formation in the Black Hills is 450 feet. The maximum thickness known to the writer is 1,335 feet penetrated in the Ohio Oil Company's Jones No. 1, southwest of the Black Hills on the Hat Creek anticline, Niobrara County, Wyoming. Several sands in the Minnelusa are the chief deep oil-producing zones in the Lance Creek field.

MISSISSIPPIAN SYSTEM

BIG SNOWY GROUP

The Big Snowy beds, probably Chester in age, were named by Harold W. Scott as a result of his work in the Big Snowy Mountains of Montana.[5] So far as the writer knows, these beds of gray, finely crystalline to dense, oölitic limestone, containing minor anhydrite, red to black clay shales, and gray, fine-grained sandstone, are not exposed in the Black Hills or on the Hartville uplift. Due to pre-Pennsylvanian erosion, variable thicknesses of the Big Snowy strata are found in the subsurface north of the Black Hills. In the deeper parts of the Williston basin, it is probable that the Big Snowy is conformable with the underlying Pahasapa or Madison limestone. Approximately 1,450 feet of beds in The California Company's Kamp No. 1, Williams County, and 500–600 feet in the Prairie Oil and Gas Company's Armstrong No. 1, Kidder County, North Dakota, are believed to belong in the Big Snowy group. A comparison between the Kidder County test and those drilled on the Baker-Glendive anticline suggests that some anhydrite was being deposited in the deeper parts of the basin at the same time that limestone and dolomite were being laid down in eastern North Dakota. The 6,700-foot oil zone on the Baker-Glendive anticline probably belongs in the Big Snowy group.

[5] Harold W. Scott, "Some Carboniferous Stratigraphy in Montana and Northwestern Wyoming," *Jour. Geol.*, Vol. 43, No. 8, Pt. 2 (November–December, 1935), pp. 1011–32.

LOWER MISSISSIPPIAN

Pahasapa-Englewood limestones.—The outcrop of the Pahasapa and the underlying Englewood forms the high limestone plateau near the crest of the Black Hills whence it probably extends eastward over the western half of South Dakota and the western two-thirds of North Dakota. The Pahasapa is light gray, very finely crystalline, massive, calcitic limestone containing small amounts of chert, oölites, and dolomite. In the Black Hills, the Englewood contains 30–60 feet of purple to gray, finely crystalline, argillaceous dolomitic limestone or dolomite. The vertical change of the Pahasapa into the Big Snowy above and the Englewood below is so gradual that so far the writer has not been able to recognize definite limits for the Pahasapa. In the region of the Baker-Glendive anticline, the basal 175–200 feet of probable Pahasapa contains many streaks of light gray coarsely crystalline limestone which here and there contains pink spots. Underlying this phase in The California Company's Kamp test, are approximately 850 feet of calcareous beds containing large amounts of gray to dark gray, finely crystalline to dense, argillaceous limestone. The lower 300 feet of the Mississippian limestone in the Carter Oil Company's Semling No. 1, Oliver County, North Dakota, also showed this shaly phase which is probably older than any Pahasapa-Englewood exposures in the Black Hills.

In The California Company's Kamp No. 1, Williams County, North Dakota, black greasy shale contains Kinderhookian conodonts.[6] It is the writer's opinion that Kinderhook shale is present in tests drilled by the Carter Oil Company, in Sec. 18, T. 141 N., R. 81 W., Oliver County, North Dakota, and in Sec. 34, T. 118 N., R. 78 W., Potter County, South Dakota. Exposures near Wind Cave in the Black Hills show no discordance of dip between the Englewood and the underlying Deadwood although this unconformity represents all of Devonian, Silurian, and Ordovician time.

DEVONIAN-SILURIAN SYSTEMS

The Devonian-Silurian strata of southeastern Manitoba are the only exposures of these rocks in or near the area under discussion. In the subsurface these beds occur in the basin north and east of the Black Hills and south and probably southwest of the Sioux uplift. In Manitoba these beds contain anhydrite, gypsum, and white to red, pure to shaly, finely crystalline to crystalline limestone and dolomite with here and there a sandy or cherty zone. The intercalated shales are generally dark red and calcareous. In southeastern South Dakota, the Siluro-Devonian beds contain white to gray, crystalline to lithographic dolomite with thin streaks of leached green shale and sandy dolomite. It is believed that approximately 625 feet of Siluro-Devonian beds occur in The California Company's Kamp No. 1, Sec. 3, T. 154 N., R. 96 W., Williams County, North Dakota. This is the maximum thickness known to occur in the Williston basin. In the east half of South Dakota there is an unconformity at the

[6] Personal communication, Charles Ryniker.

base of the Devonian because it overlaps the Ordovician dolomite. In this area the dolomite at the base of the Devonian contains scattered grains of coarse, rounded, frosted sand.

ORDOVICIAN SYSTEM

Whitewood limestone.—The Whitewood is light gray, lithographic to crystalline, granular dolomite or dolomitic limestone which thickens from a feather edge in the south-central part to 60 feet in the north part of the Black Hills. Locally it contains dark pinkish spots. Beneath the limestone there is 70 feet of dark green, sandy clay shale containing phosphate nodules. In an easterly direction a zone of white to gray, dark-spotted, fresh to weathered chert occurs approximately 150 feet above the top of the green Decorah shale. This chert is similar to a chert zone that occurs in the Galena dolomite of Iowa and Nebraska. In the Black Hills the Whitewood lies on the green shales and sandstones of the Cambrian without any discordance of dip. The Whitewood of Furnish, Barragy, and Miller is probably Richmond, Trenton, and Black River in age.[7]

In the Carter Oil Company test on the Baker-Glendive anticline, Fallon County, Montana, 815 feet of beds have been assigned to the Whitewood. Below the limestone member of the Whitewood there is dark green fossiliferous clay shale which is probably a western equivalent of the Decorah shale. The thickness of this middle Ordovician shale varies from a feather edge to 100 feet. Below this shale the drill penetrated approximately 120 feet of white, fine to coarsely crystalline, mottled limestone containing two thin beds of dark green, sandy, clay shales. This limestone is possibly the equivalent of the Platteville limestone of Iowa. West and northwest of the Sioux uplift these lower sandy limestone beds seem to be absent, for the Decorah shale is in contact with the pre-Cambrian in the stratigraphic test drilled by the Carter Oil Company in Sec. 12, T. 9 N., R. 27 E., Stanley County, South Dakota. However, in the same company's test in Sec. 34, T. 118 N., R. 78 W., there is 15–20 feet of gray, subangular to rounded, coarse sand which may be the western equivalent of the St. Peter sandstone.

LOWER ORDOVICIAN ?

Underlying the Whitewood in the Carter Oil Company test on the Baker-Glendive anticline is 5–10 feet of white St. Peter-like sandstone. Beneath this sandstone is 90 feet of light gray, fine to coarsely crystalline, sandy limestone with a few streaks of gray, fine to coarse, porous, frosted, rounded sand.

CAMBRIAN SYSTEM

Deadwood formation.—Outcrops which encircle the granite and schist in the Black Hills show that the Deadwood contains hard, brown to gray, glauconitic,

[7] W. M. Furnish, E. J. Barragy, and A. K. Miller, "Ordovician Fossils from Upper Part of Type Section of Deadwood Formation, South Dakota," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20, No. 10 (October, 1936), pp. 1329–41.

fucoid-bearing sandstone, dark green, sandy, clay shales with thin streaks of gray, crystalline dolomitic limestone and a thin basal conglomerate. The Carter Oil Company test previously mentioned penetrated approximately 500 feet of gray, glauconitic, sandy limestones, green sandy shales, and gray, fine to coarse, glauconitic sandstones which probably belong in the Deadwood formation. The maximum thickness of the Deadwood in the Black Hills is found in the north part where it contains 380 feet of rocks. It thins at the rate of 8 feet per mile toward the south and is overlapped by the lower Mississippian limestone in a test drilled in Sec. 3, T. 10 S., R. 2 E., Fall River County, South Dakota. It is the writer's opinion that red micaceous shales and conglomerate at the base of the Mississippian limestone in the Hartville uplift should be placed in the Mississippian rather than in the Deadwood.

Eastward from the Black Hills, the Cambrian grades into light gray, sandy dolomite intercalated with a few glauconitic sandstones. A well in Sec. 18, T. 90 N., R. 48 W., South Dakota, penetrated 233 feet of Cambrian sandy dolomite containing 55 feet of sandstone near the middle and a basal conglomerate. The Deadwood unconformably overlies the pre-Cambrian.

PRE-CAMBRIAN ROCKS

In the area under discussion, the pre-Cambrian crops out only in the Black Hills and the Sioux uplift. In the latter area it is represented by the purplish red Sioux quartzite. In the Black Hills the pre-Cambrian contains schists, granite, pegmatite, and various other types of igneous and metamorphic rocks. The pre-Cambrian is found beneath the glacial drift in a large area of western Minnesota.

STRUCTURAL GEOLOGY

Figure 2 is a structure map which is contoured on the top of the Dakota sandstone. It shows a large area of rocks with low dip in eastern North and South Dakota. This relatively flat area forms the east flank of the Williston basin, which extends from the northeast corner of Montana into north-central Nebraska. The Cambridge arch with its superimposed Chadron dome, the Black Hills, and the Baker-Glendive anticline form the west flank of this basin. In southeast Wyoming, the north part of the Denver basin is shown. The east dip from the Laramie Range to the bottom of this basin is very steep. There is a fold extending northeast from the Laramie Mountains toward the Black Hills. The Hartville uplift, the Hat Creek anticline, and the Old Woman anticline are surface expressions on this broad arch. From the crest of the Black Hills, the rocks dip west at a fairly uniform rate almost to the foothills of the Big Horn Mountains, thereby making the deepest part of the Powder River Basin a short distance east of the axis of the mountain range. Many of the men mapping structure in the surface rocks of the Dakotas find that there are well developed trends. The local structures, covering 6–20 square miles, with closures of 30–60 feet, occur on these trends many of which can be traced 30 miles or more. In the east-central Dakotas the surface

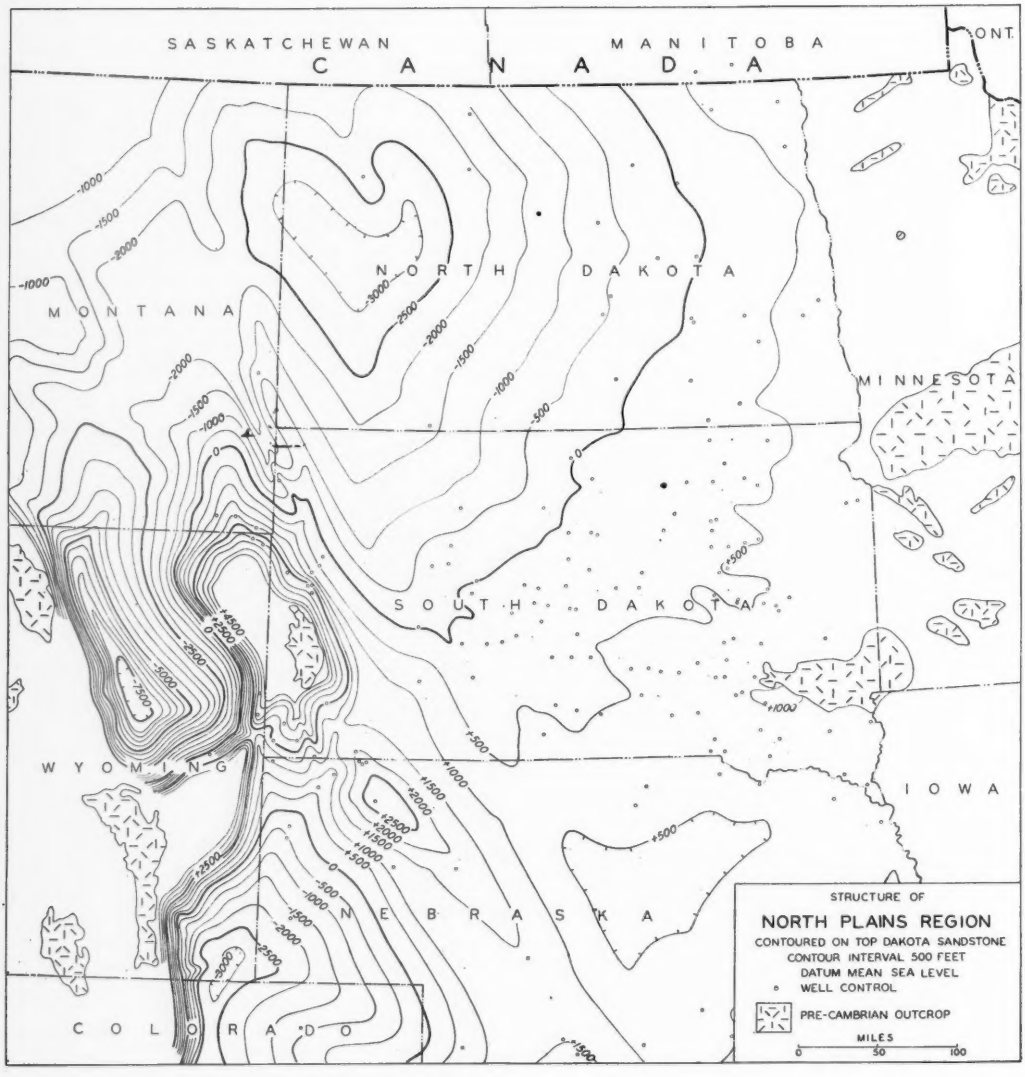


FIG. 2.—Structure of Northern Great Plains region, contoured on top of Dakota sandstone.

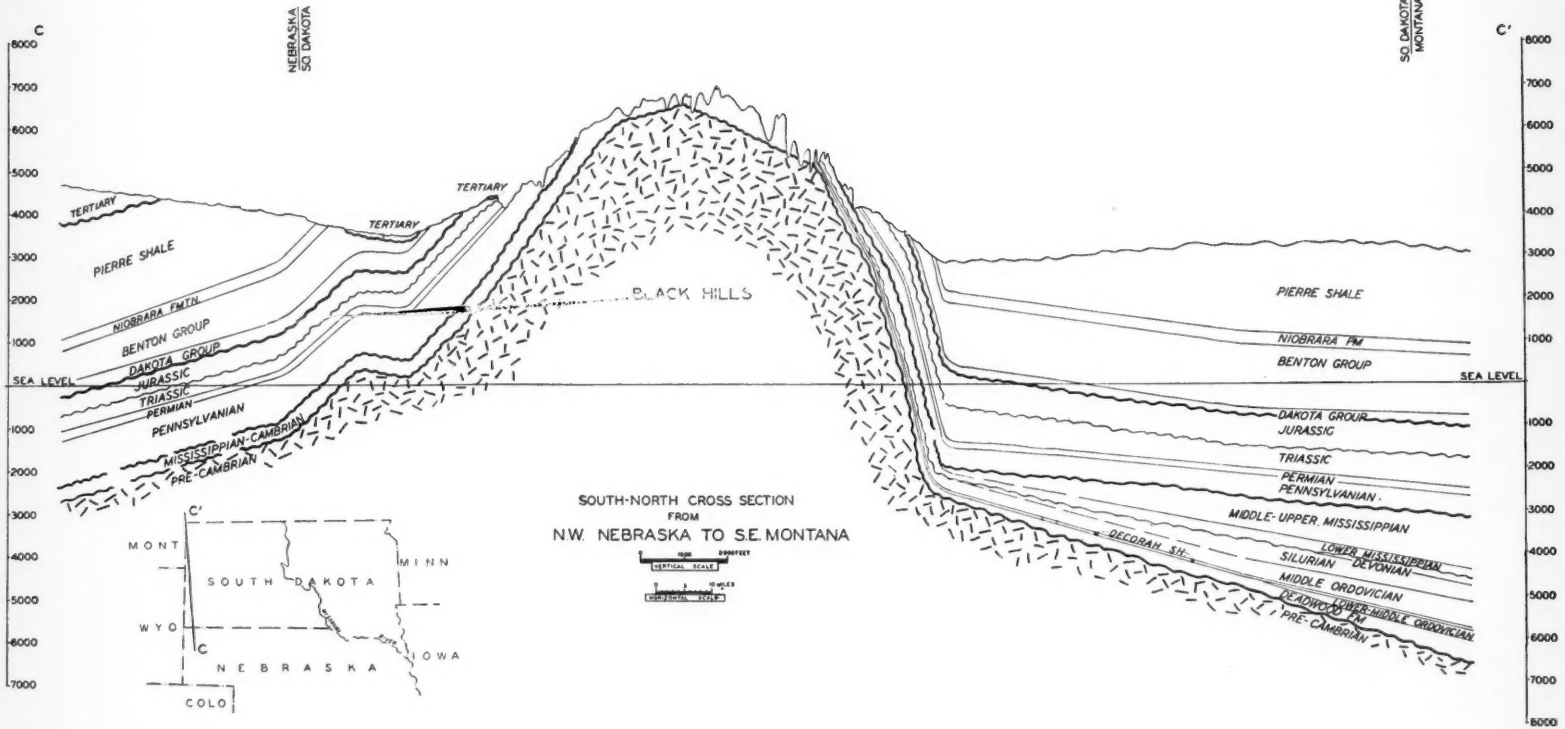


FIG. 3.—South-north cross section from northwest Nebraska to southeast Montana.

structures trend northeast and southwest, but the structures in the west third of both North Dakota and South Dakota are reported to trend west of north.

Darton[8] mentions faulting near Jewel Cave, on Whitewood Creek below Deadwood, in Deadman Gulch, north of Roubaix, around Bear Butte, in Nevada Gulch, and northwest of Lead on Bogus Jim Creek. So far as is known to the writer, there is no evidence of faulting in any other part of the area under discussion.

Figure 3 is a cross section which extends north from the Union Oil Company's Agate No. 1, Sioux County, Nebraska, across the west side of the Black Hills to the Carter Oil Company's Northern Pacific Railroad No. 1, in Fallon County, Montana. The first Paleozoic period of tilting to affect the Dakota area occurred in post-Deadwood, pre-Decorah time as shown by a north-thickening wedge of pre-Decorah Ordovician limestones. There are approximately 220 feet of these limestones and thin sandstones in the Carter Oil Company test on the Baker-Glendive anticline that are not present in exposures in the Black Hills. In the Black Hills area there may have been post-Richmond, pre-Silurian tilting, for the Whitewood thickens to 815 feet in the northernmost well in the section. However, until more evidence is available, the writer considers this is the normal regional thickening of the Whitewood. This section shows a wedge of probable Siluro-Devonian dolomites pinching out on the north flank of the Black Hills. There was northward tilting in pre-Mississippian time, for in a southerly direction the lower Mississippian limestone rests on the beds ranging from Devonian to pre-Cambrian in age. There was northerly tilting in pre-Pennsylvanian time because the Minnelusa sandstone rests on successively older Mississippian rocks near the Black Hills.

The upper and middle Mississippian rocks, which are not exposed in the Black Hills, attain a thickness of 1,450 feet in The California Company's Kamp No. 1, Williams County, North Dakota. The Kamp well is about 250 miles north of the Black Hills. The lower Mississippian beds thicken northward approximately 750 feet between the Carter test on the Baker-Glendive anticline and the Kamp test. The Jurassic and Triassic beds thin slightly toward the north, but the thickness of the Permian and Pennsylvanian is fairly uniform in that direction. In the Cretaceous strata, the thickness of the Niobrara remains constant north of the Black Hills. The Benton thins slightly in the same direction but the Dakota thickness increases. All post-Permian beds become thinner between the Black Hills and the southern limits of the section. The Permian reverses this tendency and thickens approximately $1\frac{1}{2}$ feet per mile. This southward thickening is undoubtedly due to the addition of basal beds. Although there is very little evidence derived from well study, it is probable that the Pennsylvanian thickens in the area covered by the south half of the section.

In the Black Hills *Folio*, Darton states that the basal Sundance sand rests on

[8] N. H. Darton and Sidney Paige, "Central Black Hills, South Dakota," *U. S. Geol. Survey Geol. Atlas Folio 219* (1925).

the eroded surface of the Spearfish in Hell Canyon and Centennial Prairie. Since the Twin Creek, lower Sundance, seems to be present only in the basin north and west of the Hills, it is probable that the eastern Sundance represents only the upper part of the formation as it is developed in the west part of the Williston basin. Although both the Sundance and the underlying Spearfish thin toward the east, it is the writer's opinion that the northwest tilting and consequent erosion of the Spearfish occurred in post-Triassic, pre-Sundance time and that as erosion lowered the high area at the east, the Sundance sea encroached farther and farther upon it.

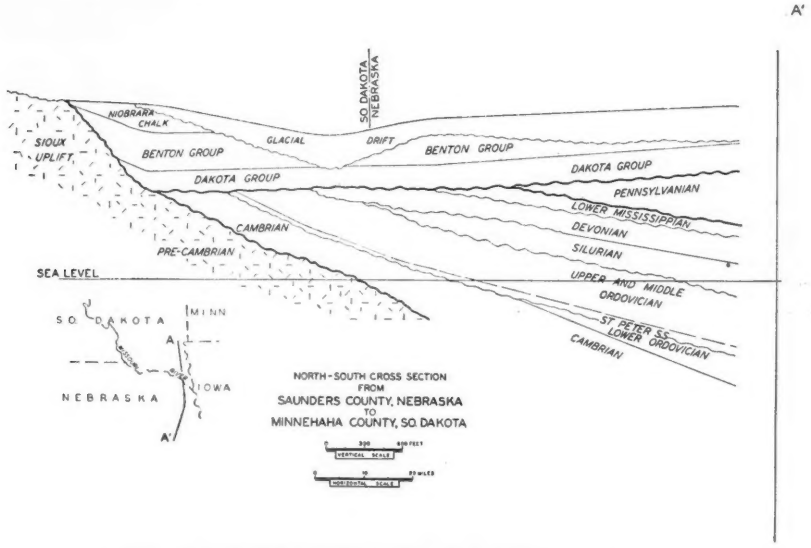


FIG. 4.—North-south cross section from Saunders County, Nebraska, to Minnehaha County, South Dakota.

Figure 4 is a section from Saunders County, Nebraska, north to the Sioux uplift in southeast South Dakota. One should notice that the top of the Dakota sandstone dips north from Saunders County to the very edge of the Sioux uplift. This north dip can be verified by outcrops. On the north flank of the Sioux uplift, Niobrara chalk overlaps the pre-Cambrian Sioux quartzite. Although exposures of the contact with the quartzite are lacking on the south side of this uplift, it is assumed a condition similar to that on the north side exists; that is, beds ranging from the Niobrara to the Dakota are in contact with the quartzite. South of the uplift, the Dakota rests successively on Cambrian, Ordovician, Devonian, Mississippian, and Pennsylvanian. The absence of the Maquoketa shales as far south as Saunders County, Nebraska, suggests that there was tilting during or after Ordovician time because the Silurian dolomite rests on eroded Galena dolomite,

the normally intervening Maquoketa shale being absent. The fact that Devonian dolomite lies on eroded Ordovician Galena dolomite in a test drilled by the Sioux Valley Oil and Gas Company, Sec. 18, T. 90 N., R. 48 W., Union County, South Dakota, proves that there was pre-Devonian southerly tilting and erosion in the area of the Sioux uplift. There was southward tilting preceding the St. Peter sea invasion of the north part of the central United States because the St. Peter sandstone rests on successively older Ordovician, Cambrian, and possibly pre-Cambrian, as one approaches the Sioux uplift. This same overlap occurs from the Ozark Mountains on the south to Wisconsin and Minnesota on the north.

Figure 5 is a section extending from northwestern to eastern South Dakota. It shows the eastward thinning of all Cretaceous strata younger than the Dakota. The eastward thickening of the Dakota was probably caused by the deposition of sand near the Sioux uplift at the time that the Graneros shale was being laid down in the deeper parts of the basin. Wells in Manitoba and North Dakota show that the Jurassic overlaps beds as old as the Devonian. Although pre-Cretaceous erosion of the Jurassic in this area has possibly removed all evidence that the Jurassic ever overlapped beds lower than the Devonian, it is the writer's opinion that at one time Jurassic was in contact with beds as old as pre-Cambrian in eastern North Dakota. There is a thin section of Triassic in the Gulf Oil Corporation's Hunter No. 1, Sec. 28, T. 3 N., R. 16 E., Pennington County, and it is absent in the test drilled in Sec. 12, T. 9 N., R. 27 E., Stanley County, South Dakota. Samples from the Carter Oil Company's Semling No. 1, Sec. 18, T. 141 N., R. 81 W., Oliver County, North Dakota, show that the Sundance has overlapped the Spearfish-Minnekahta limestone and part of the Opeche formation at that point. These data suggest that the Triassic Spearfish formation is confined to the west half of North and South Dakota. The Pennsylvanian rests on successively older Mississippian beds in an easterly direction. Since there is no evidence known to the writer, suggesting that the Pennsylvanian strata overlap the beveled edges of the Devonian, Silurian, Ordovician, and older beds, it is shown as overlapping only the upper, middle, and part of the lower Mississippian on the west flank of the Sioux uplift. Two tests drilled for stratigraphic information by the Carter Oil Company in Sec. 12, T. 9 N., R. 27 E., and Sec. 34, T. 118 N., R. 78 W., respectively, show that the Decorah shale, Black River in age, or possibly St. Peter sandstone, lower Ordovician, is in contact with pre-Cambrian rocks. In Manitoba, shales at the top of the Winnipeg sandstone, which also overlies the pre-Cambrian, contain fossils that indicate Black River age.[9] This would make the Winnipeg shale equivalent to at least a part of the Minnesota Decorah shale. These data indicate that the Cambrian and pre-St. Peter Ordovician dolomites and sandstones, which are present on the south flank of the Sioux uplift, are absent in Manitoba, eastern North Dakota, and as far south as Stanley County, South Dakota.

[9] G. S. Hume, "Oil and Gas in Western Canada" (2d ed.), *Geol. Survey Canada Econ. Geol. Ser.*, No. 5 (1933), p. 257.

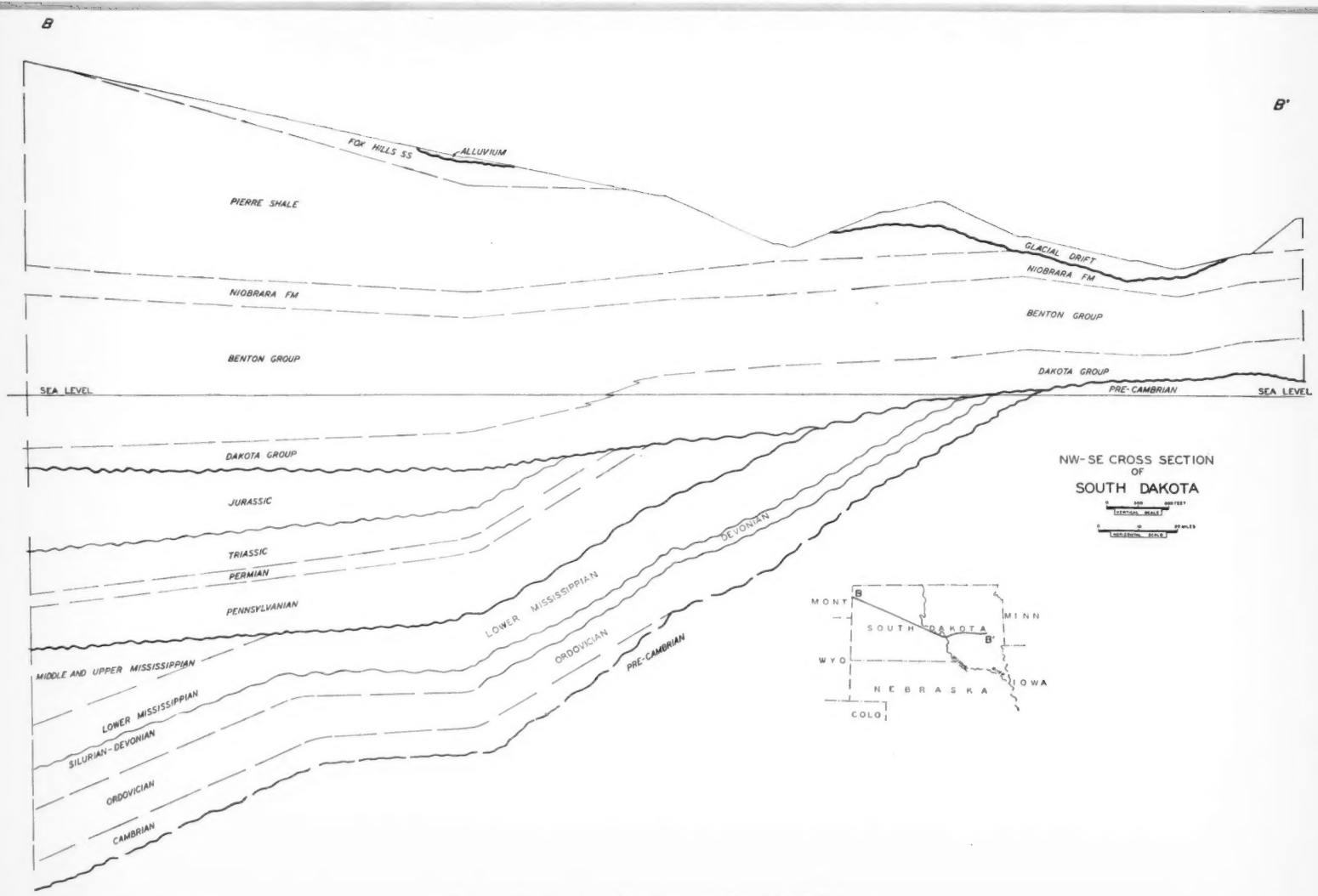


FIG. 5.—Northwest-southeast cross section of South Dakota.

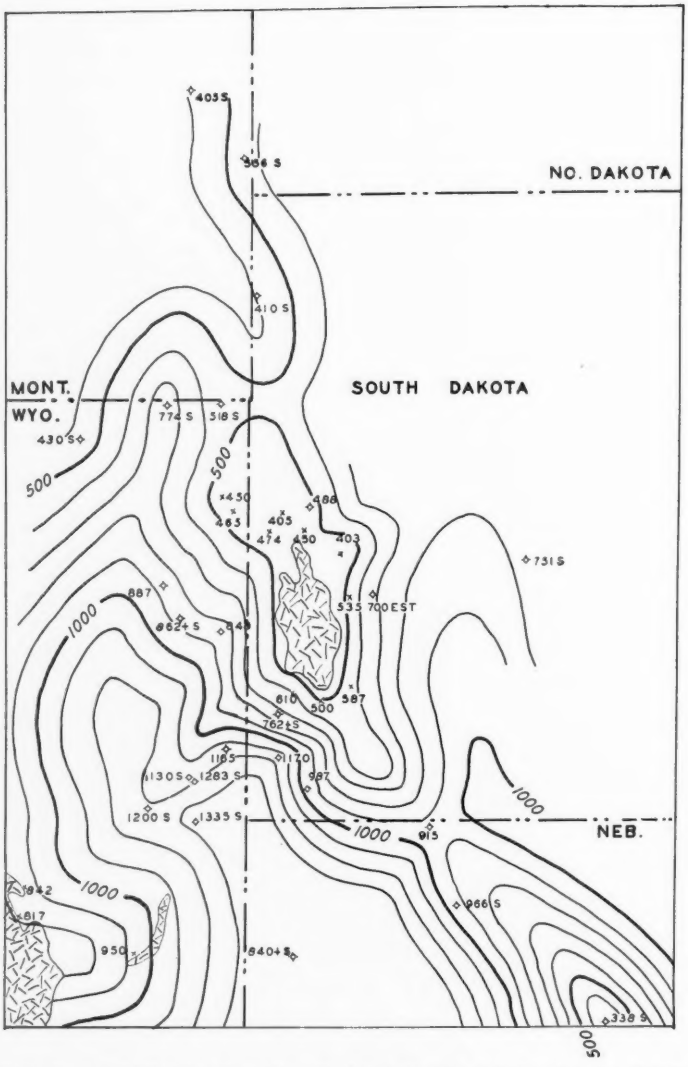


FIG. 6.—Isopach map of Minnelusa formation. Contour interval, 100 feet. x, location of surface section. Well symbol shows location of well data (751-S, sample data). Scale: 1.375 inches = 25 miles.

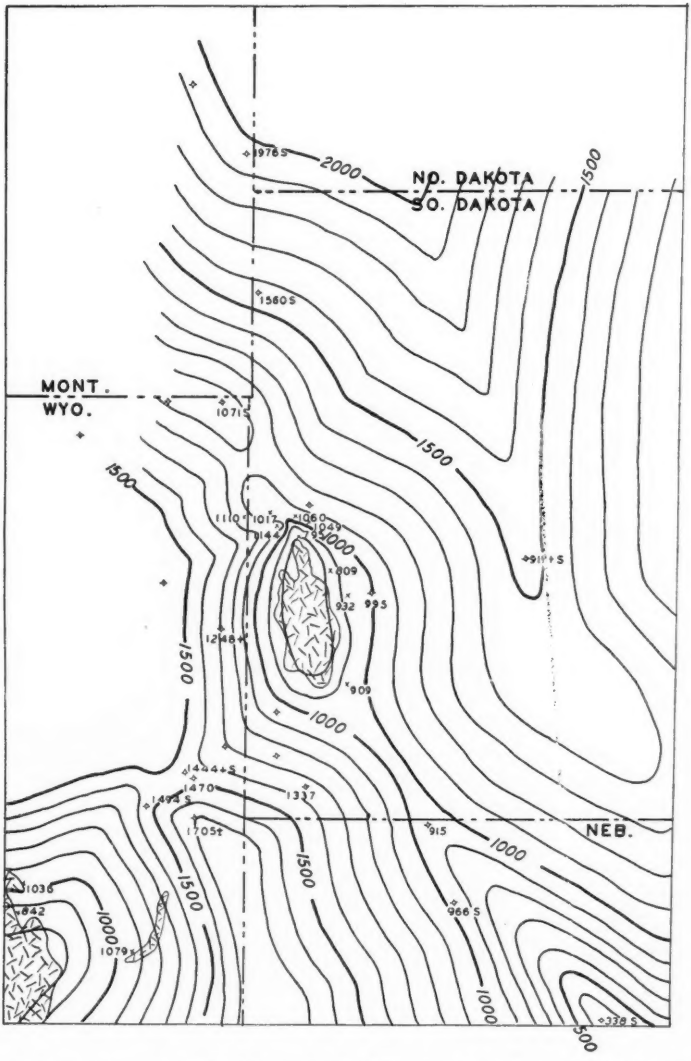


FIG. 7.—Isopach map of combined Pennsylvanian Minnelusa formation and Mississippian Pahasapa and Englewood formations. Contour interval, 100 feet. x, location of surface section. Well symbol shows location of well data (751-S, sample data). Scale: 1.375 inches = 25 miles.

Figures 6 and 7 show that there was local folding in the Black Hills area in post-Mississippian, pre-Pennsylvanian time. A small x has been used to show the locations of measured sections, which were compiled from published information. Well locations are shown by the conventional symbol. The letter S placed on the right side of the numerical thickness denotes that the data were obtained from microscopic examination of well cuttings. Figure 6, an isopach map of the Permo-Pennsylvanian Minnelusa formation, shows that the thinnest sections of the Minnelusa are found on the north flank of the Black Hills where as little as 405 feet is exposed. Samples from a well drilled at Rapid City, on the steep east flank of the Hills, show that approximately 700 feet of Minnelusa was penetrated there. On the south flank 1,170 feet of these beds were drilled, and on the west side 848 feet were penetrated. Figure 7 shows the combined thicknesses of the Minnelusa and the Mississippian Big Snowy, Pahasapa, and Englewood limestones. Here also, the thinnest section is found on the north flank of the Hills where 795 feet of Minnelusa-Englewood strata were measured. Samples from the Bull Creek well of the Union Oil Company of California, Sec. 3, T. 57 N., R. 62 W., Crook County, Wyoming, show that 1,071 feet of Minnelusa-Englewood strata are present down the north flank of the Black Hills. At Rapid City, 995 feet of these beds were penetrated. On the south flank of the Hills, 1,337 feet of Minnelusa-Englewood beds were drilled, and on the west flank 1,248 feet were penetrated without reaching pre-Mississippian strata. These data show that there was between 200 and 300 feet of local thinning in the Minnelusa-Englewood rocks in the Black Hills area. Consequently, the writer believes that in pre-Pennsylvanian time the Black Hills was an anticline with 200–300 feet of local closure as opposed to the prevailing idea that anticlinal folding of the Black Hills did not take place until post-Cretaceous time. The Cambridge arch was folded in post-Mississippian, pre-Pennsylvanian time for the Minnelusa is in contact with pre-Cambrian a short distance south of the South Dakota-Nebraska line. The presence of provable pre-Pennsylvanian folding on the arch less than 75 miles southeast of the south part of the Black Hills suggests within itself that there should be pre-Pennsylvanian folding in the Black Hills area. Furthermore, in a personal communication, E. C. Reed of the Nebraska Geological Survey reports that there is approximately 100 feet more of Mississippian on the flanks of the Hartville uplift than is present near the crest. This fact suggests that there was local folding in pre-Pennsylvanian time on this uplift also.

There was tilting toward the south and west in pre-Dakota time because that formation successively overlaps older rocks in northerly and easterly directions. There is some evidence that the Lance rests on successively older Fox Hills in an easterly direction in South Dakota. Tertiary igneous intrusions into the sedimentary rocks in the north part of the Black Hills formed many steep-sided domes. There was structural deformation after the Fort Union was deposited, for these beds are folded on the Baker-Glendive anticline of eastern Montana. In a personal communication, W. L. Russell states that Oligocene White River

beds in South Dakota have been gently folded. This is the last known period of deformation to affect the area.

SUMMARY OF TILTING AND UPLIFT

Post-Oligocene
Post-Fort Union
Possibly post-Fox Hills, pre-Lance
Post-Morrison, pre-Lakota
Post-Spearfish, pre-Sundance
Post-Chester, pre-Pennsylvanian
Post-Devonian, pre-Mississippian, shown by absence of Chattanooga shale near Sioux uplift
Post-Silurian, pre-Devonian, in area of Sioux uplift
Post-Galena, pre-Silurian, in area of Sioux uplift
Post-Beekmantown, pre-Chazy, in area of Sioux uplift
Post-Deadwood, pre-Decorah
Pre-Cambrian folding

PRE-PENNSYLVANIAN PALEOGEOLOGIC MAP

Figure 8 represents the areal geology of the north-central Great Plains at the time that the Pennsylvanian seas advanced over the eroded land surface. This pre-Pennsylvanian map was prepared by plotting with different symbols the age of the different rocks that are in known contact with the basal Pennsylvanian beds. Where the data were obtained from outcrops, the edge of the Pennsylvanian is shown by a shaded line, the downdip side of which contains a heavily stippled border. Where subsurface control was available, the writer differentiated between the data obtained by microscopic examination of formation cuttings and that secured from drillers' logs by using a larger black dot to denote the location of the test supplying the sample data. In this manner, one can see the degree of control on which the period boundaries are based. This map shows a large high pre-Cambrian area extending northward from Colorado to the longitude of Wheatland, Wyoming, about 80 miles north of the Colorado line. Although there is very little control in the intervening space, the writer joins this high pre-Cambrian area with that of a high granite area extending northwestward from the Central Kansas uplift. It is improbable that the Siluro-Devonian rocks will be found in northwestern Nebraska and in the shallow syncline separating the Black Hills from the Chadron dome. The absence of any rocks of this age in the Black Hills, on the Hartville uplift southwest of the Hills, and in the intervening area, as shown by deep wells drilled to date, leads one to the foregoing conclusion.

Beds of Cambro-Ordovician age are overlapped by the lower Mississippian limestone in the Black Hills. On the east flank of the Central Kansas uplift, the Pennsylvanian overlaps beds down to and including the pre-Cambrian. The Pennsylvanian is also in contact with the Cambro-Ordovician rocks along the east flank of the Cambridge arch which is a northwest extension of the Central Kansas uplift. Bredthauser *et al.* Bookwalter No. 1, Sec. 27 ? T. 18 N., R. 13 W., Valley County, Nebraska, penetrated approximately 400 feet of Cambro-Ordovician rocks beneath the Pennsylvanian. The thin pre-Pennsylvanian section in this well, which is located far east of the axis of the Cambridge arch, suggests the probability that there is a high pre-Cambrian area extending northeast from the

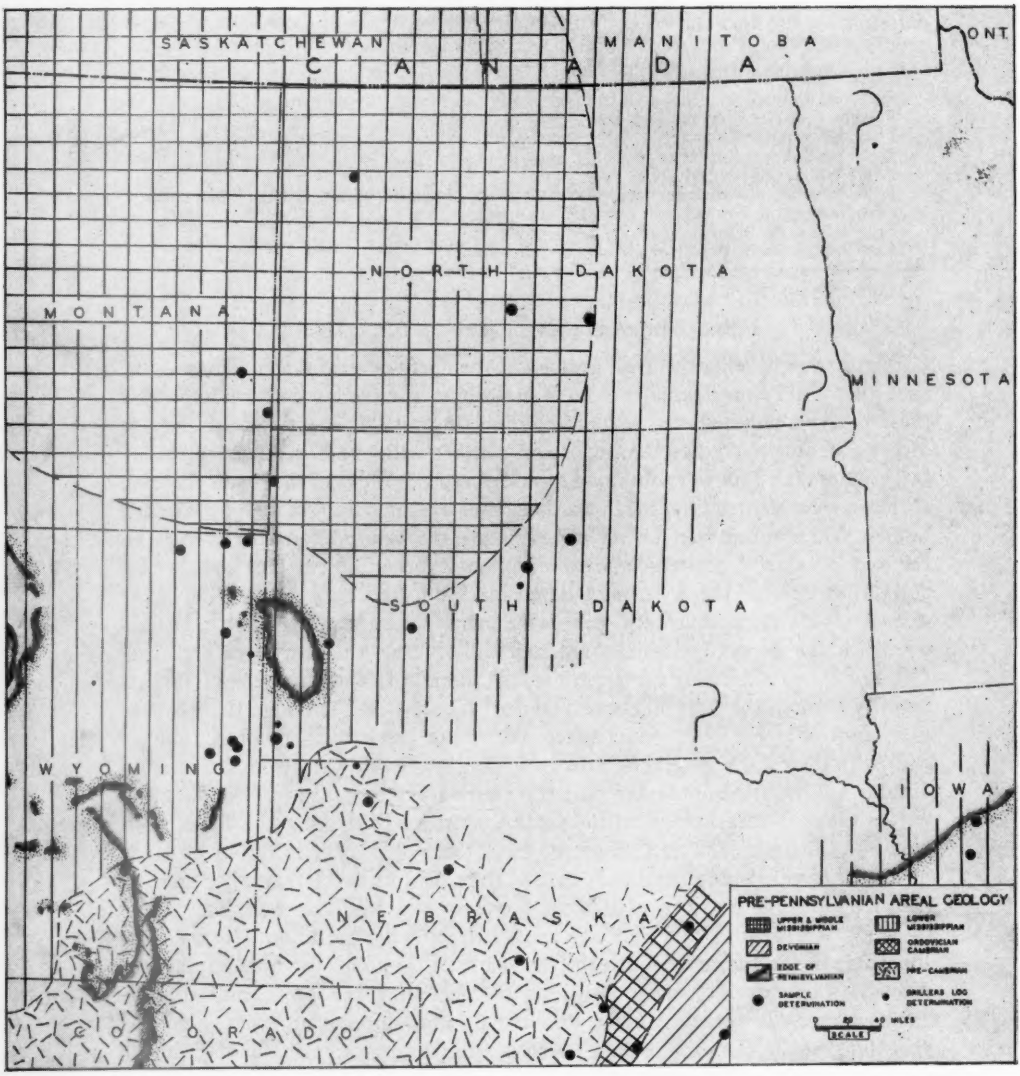


FIG. 8.—Pre-Pennsylvanian areal geology.

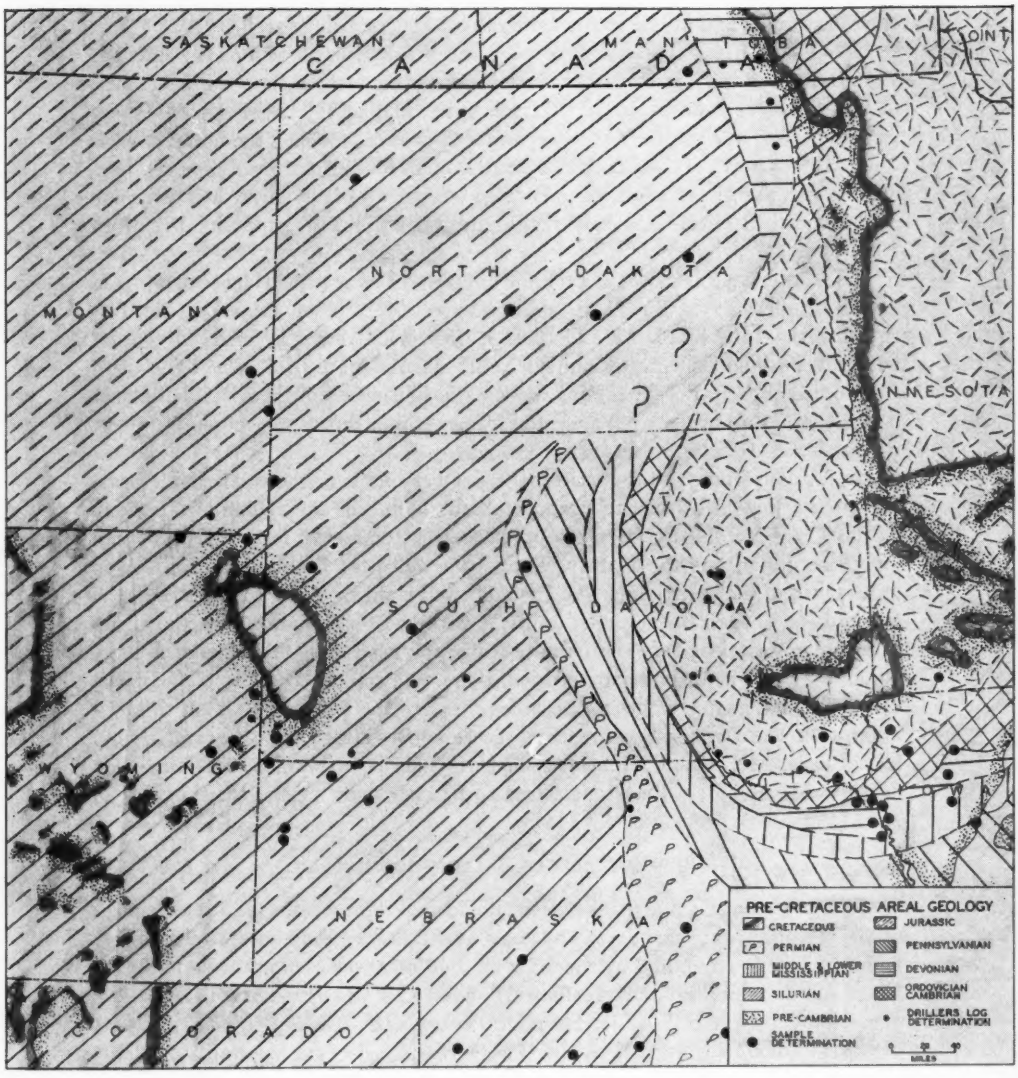


FIG. 9.—Pre-Cretaceous areal geology.

arch to the Sioux uplift. The Devonian overlaps the Silurian on the south flank of the Sioux uplift and on the southeast flank of the Cambridge arch.

The lower Mississippian seas covered the Black Hills as well as the Laramie Mountains and the Big Horn Mountains, depositing a thick series of limestones. It is possible or even probable that the upper and middle Mississippian rocks were deposited over much of the area under discussion, for they are found in wells only 50 miles north of the Black Hills. Subsequent folding and pre-Pennsylvanian erosion was not of sufficient magnitude to remove all of the lower Mississippian rocks in the Black Hills, the Hartville uplift, and the Laramie and Big Horn mountains.

The Cambridge arch was again folded in post-Triassic time because in a southeasterly direction, the Sundance rests on successively older Triassic. The Morrison overlaps the Sundance and the Spearfish beds and it is found in contact with the Permian in Grant County, Nebraska. As the magnitude of the post-Cretaceous or early Eocene folding was greater in the area of the Black Hills than it was in the Cambridge arch area, the former stands out as the more prominent feature on the basis of present areal geology.

So far as is known to the writer, there is very little evidence available bearing on the possibility of pre-Pennsylvanian folding in the region of the Sioux uplift. There is a short section of approximately 100 feet of lower Mississippian limestone underlying the Pennsylvanian in a well near Fremont, Nebraska, 75 miles south of the uplift. Since the Fremont well is much closer to the axis of the Granite Ridge than to the Sioux uplift, it is the writer's opinion that the structural influence exerted by the Granite Ridge folding is responsible for the large amount of pre-Pennsylvanian erosion there. A well at Dennison, Crawford County, Iowa, is approximately 20 miles closer to the Sioux uplift than the Fremont well. The Dennison test reached the Devonian strata after penetrating 339 feet of lower Mississippian limestone beneath the Pennsylvanian. This thickness of lower Mississippian limestone seems to be very near normal for this part of Iowa.

Pre-Cretaceous Paleogeologic Map

Figure 9 is a pre-Cretaceous paleogeologic map representing the areal geology of the unconformity surface upon which the Dakota group of sediments were laid down. It was prepared by the same method that was used in the compilation of the one for the pre-Pennsylvanian. It shows that in an easterly direction the Jurassic overlaps the Triassic, Permian, Pennsylvanian, Mississippian, and part of the Devonian in North Dakota. The Jurassic is in turn overlapped by the Dakota which finally rests on the pre-Cambrian Sioux quartzite. Shale cuttings containing Jurassic fossils were found in a test drilled by the Commonwealth Oil and Gas Company in Sec. 26, T. 2 N., R. 9 W., first principal meridian of Manitoba. These Jurassic shales unconformably overlie Devonian strata according to the Canadian Geological Survey. According to the writer's interpretation,

basal Sundance rocks are in contact with Permian Opeche shale, in the test drilled by the Carter Oil Company in Sec. 18, T. 141 N., R. 81 W. It is a matter of opinion whether in eastern South Dakota the Jurassic overlaps the older rocks as shown in North Dakota or whether the Permian to Ordovician strata occur as narrow bands between the Jurassic and the west edge of the pre-Cambrian quartzites, schists, and granites. In both the Carter Oil Company stratigraphic tests in Sec. 12, T. 9 N., R. 27 E., Stanley County, and Sec. 34, T. 118 N., R. 78 W., Potter County, South Dakota, sandstones of the Dakota group are in contact with Minnelusa rocks. This suggests that the North Dakota Jurassic overlap may not be present in South Dakota. On the other hand, the presence of large numbers of the cigar-shaped *Belemnites densus*, a Sundance index fossil, associated with many Sioux quartzite pebbles in the glacial drift of Cherokee County, northwestern Iowa, suggests that this drift came from the northwest where the Jurassic was closely associated with the Sioux quartzite. Correlation of subsurface information obtained from many wells is the only method by which this problem can be solved.

POSSIBLE PRODUCING ZONES

	South Dakota	*North Dakota*	*Wyoming*	*Montana*	*Nebraska*
Eagle sandstone		*	*	*	
Wall Creek sandstone			*	†	
Newcastle sandstone	†		*	†	
Dakota group	*	*	*	*	
Sundance sandstone	†		*		
Minnekahta-Embar limestone			*		
Minnelusa formation	*		*	†	
Big Snowy group	†	†	†	*	
Pahasapa limestone	†		†	†	
Devonian-Silurian dolomite	†	†		*	*
Whitewood limestone	†				
Middle and Lower Ordovician limestone	†				

* Producing oil or gas.
† Showings of oil or gas.

The possible oil- and gas-producing zones in the Dakotas are discussed, beginning with the youngest and continuing to the oldest. About 25 miles west of Westhope, gas was produced from a pool near Mohall, Renville County, North Dakota. This gas occurred at a depth of approximately 280 feet in beds of Upper Cretaceous age, probably upper Fox Hills. Nine and one-half miles south of Westhope, Bottineau County, North Dakota, gas wells with an average open flow of $2\frac{1}{2}$ million cubic feet were completed at a depth of 150–200 feet. This gas, which was piped into Westhope, was produced from a sandy lense at the base of the glacial drift or in the top of the underlying Pierre shale. Another small Pierre gas field was developed near Lansford in the same county.

On the Baker-Glendive anticline, gas has been produced for a long time from the Judith River and Eagle, sands found in the western equivalent of the Pierre

shale.[10] This sandstone extends into western North Dakota but apparently it is absent in most of South Dakota.

The Wall Creek and Newcastle sands which occur in the Benton group, both produce oil and gas in eastern Wyoming. It is possible that the Newcastle sand will be found some distance east of the Dakota-Montana boundary. A well in Lawrence County, South Dakota, is reported to have had a showing of oil in the Newcastle sand.

A wide area on both sides of the Missouri River has produced gas with the Dakota artesian water. This gas has been used locally for a number of years. Pierre, South Dakota, and Edgeley, North Dakota, have marketed gas developed from this source. The writer has no record of any live oil being found in the rocks of the Dakota group in North Dakota or South Dakota, but Noel Evans[11] reports a seep in these rocks on Pine Ridge, west of Sundance, Wyoming.

The Sundance sand, which produces oil in several eastern Wyoming fields, is present in a large part of the Dakotas. The Embar, which is the western equivalent of the Minnekahta limestone, produces oil in Wyoming. In several places in South Dakota, the Minnekahta gives off a petroliferous odor when it is struck by the hammer. The Minnelusa formation contains several rich pay zones in the Lance Creek field. This formation produced oil in two wells in Sec. 34, T. 6 S., R. 2 E., Custer County, South Dakota. For several days, a well in Red Canyon, Sec. 17, T. 8 S., R. 3 E., Fall River County, South Dakota, produced 2–5 barrels of 41° gravity oil from the Minnelusa. Three wells produced oil from the 6,700-foot dolomite, probably Big Snowy in age, on the Baker-Glendive anticline, Fallon County, Montana. Several tests in North Dakota and South Dakota have reported showings of oil in various zones in the Big Snowy strata as well as in the underlying Pahasapa limestone. The writer believes that the deep oil on the Baker-Glendive structure is coming from beds of Devonian or Silurian age. Other tests in North Dakota and South Dakota have recorded showings of oil from similar rocks. Several showings of oil in beds of Cambrian or Ordovician age have been reported in the State Royalty Petroleum Company test, Sec. 35, T. 18 N., R. 1 E., Harding County, South Dakota.

If any oil can be found in the wedge belts, the Dakotas are destined to become a major producing area on account of the wide extent of the wedges of porous beds.

North Dakota and South Dakota contain strata in the Cretaceous, Jurassic, Permian, Pennsylvanian, Mississippian, and Siluro-Devonian that have produced oil in near-by regions. The well on the Camp Crook anticline, Sec. 35, T. 18 N., R. 1 E., South Dakota, had a good showing of live oil in strata of Cambrian or Ordovician age according to scout reports. The North Dakota Williston basin continues northwestward into northern Alberta and northeastern British Colum-

[10] John G. Bartram and Charles E. Erdmann, "Natural Gas in Montana," *Geology of Natural Gas* (Amer. Assoc. Petrol. Geol., 1935), pp. 245–76.

[11] Consulting geologist, Houston, Texas.

TENTATIVE CORRELATION TABLE

			WILLISTON BASIN	EASTERN WYOMING	WESTERN IOWA
		QUATERNARY	ALLUVIUM GLACIAL DRIFT	ALLUVIUM	ALLUVIUM GLACIAL DRIFT
CENOZOIC	TERTIARY	OLIGOCENE	BRULE CLAY CHADRON FM.	WHITE RIVER GROUP	
		EOCENE	ABSENT	WASATCH FM.	ABSENT
			FT. UNION FM.	FT. UNION FM.	
		PALEOCENE	LANCE FM.	LANCE FM.	
MESOZOIC	CRETACEOUS		FOX HILLS FM.	FOX HILLS FM.	
			PIERRE SHALE JUDITH RIVER AND EAGLE SS *	LEWIS SH.	
				MESAVERDE FM.	
				STEELE SH. SHANNON SS *	
			NIOBRARA FM.	NIOBRARA FM.	NIOBRARA FM.
				CARLILE SH.	CARLILE SH.
			BENTON GROUP	FRONTIER FM. WALL CREEK SS *	GREENHORN IS.
			MUDDY SS △	MOWRY SH. NEWCASTLE SS *	GRANEROS SH.
				THERMOPOLIS SH.	
			DAKOTA SS △	DAKOTA SS *	DAKOTA GROUP
			FUSON SH.	FUSON SH.	
			LAKOTA SS △	LAKOTA SS *	
	JURASSIC		MORRISON SH.	MORRISON SH.	ABSENT
			SUNDANCE FM. △	SUNDANCE FM. *	
	TRIASSIC		SPEARFISH FM.	SPEARFISH (CONDRA 1940)	
	PERMIAN			FREEZEOUT (CONDRA 1940)	
				FORELLE (CONDRA 1940)	
				GLENDO SH. (CONDRA 1940)	
			MINNEKAHTA IS.	MINNEKAHTA IS.	FT. DODGE GYPSUM?
			OPECHE SH.	OPECHE SH.	
	PENNSYLVANIAN		MINNELUSA FM. *	MINNELUSA FM. *	PENNSYLVANIAN
PALEOZOIC	MISSISSIPPIAN	UPPER	BIG SNOWY GROUP △	BIG SNOWY GROUP △	
		MIDDLE			STE. GENEVIEVE IS. ST LOUIS IS. SPERGEN IS.
		LOWER	PAHASAPA IS. △	PAHASAPA IS. △	WARSAW FM. KEOKUK IS. BURLINGTON IS.
		KINDERHOOKIAN	ENGLEWOOD IS. CHATTANOOGA-LIKE SH.	ENGLEWOOD IS.	KINDERHOOK SH.
	DEVONIAN	UPPER	PRESENT ? △	PRESENT?	SHEFFIELD FM. LIME CREEK FM. SHELL ROCK FM. CEDAR VALLEY FM. WAPSIPINICON FM.
	SILURIAN	MIDDLE	PRESENT ? △	PRESENT ?	NIAGARAN
		LOWER			ALEXANDRIAN
	ORDOVICIAN	RICHMOND	WHITEWOOD IS. DECORAH SH. PRESENT? ST PETER? SS △	WHITEWOOD IS. DECORAH SH. PRESENT ? ST PETER? SS	MAQUOKETA SH. GALENA DOL. DECORAH SH. PLATTEVILLE IS. ST PETER SS
		TRENTON			
		BLACK RIVER			
		CHAZY			
		BEEKMANTOWN	ABSENT	ABSENT	PRAIRIE DU CHIEN DOL.
	CAMBRIAN	UPPER	DEADWOOD FM.	DEADWOOD FM.	TREMPELEAU FM. FRANCONIA SS DRESBACH SS
			PRE-CAMBRIAN	PRE-CAMBRIAN	PRE-CAMBRIAN

* OIL AND GAS PRODUCTION
△ SHOWS OF OIL OR GAS

bia. Oil and gas have been produced on the southwest side of this basin at Turner Valley, Bow Island, Medicine Hat, and Foremost. On the north flank of the Canadian extension of the basin, oil and gas are produced on the Athabaska River, Peace River, Battle River, and at Viking. Oil and gas occur at Turner Valley in Cretaceous sandstone and Paleozoic limestone and at Bow Island, Battle River, Viking, Medicine Hat, Foremost, Athabaska, and Peace River in Cretaceous sandstones in the Montana and Colorado groups. Since there is commercial production on the north and west sides of the Canadian part of the Williston basin, it is logical to assume that under proper structural conditions oil and gas will be found in similar rocks in the Dakota part of this basin.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 26, NO. 10 (OCTOBER, 1942), PP. 1585-1593, 1 FIG.

INTERBASIN PENNSYLVANIAN CORRELATIONS, ILLINOIS AND IOWA[1]

J. M. WELLER,[2] H. R. WANLESS,[3] L. M. CLINE,[4] AND D. G. STOOKEY[5]
Urbana, Illinois, Ames, Iowa, and Fort Worth, Texas

ABSTRACT

A joint field conference by representatives of the Illinois and Iowa geological surveys has examined a 350-foot Pennsylvanian section in adjacent parts of these states extending from the so-called Seahorne sandstone of Illinois (middle Cherokee) to the Trivoli-Hertha limestone (lower Missouri) and agrees upon the correlation of most of the important intermediate strata. Additional field studies by others now make possible the precise correlation of an important part of the Pennsylvanian system from Illinois to Kansas. New names are proposed for two cyclothems recognized in Illinois and Iowa.

INTRODUCTION

Attempts to correlate precisely individual strata occurring in the different American coal basins have been neither numerous nor particularly successful. The first detailed correlations of strata in the Eastern and Western Interior basins not based exclusively on paleontologic evidence were made by J. M. Weller[6] and J. B. Knight[7] as the result of a brief joint reconnaissance in 1928. Further observations in the northern part of the Western Interior basin were made by Weller in 1930.[8] A number of significant localities were revisited with H. R. Wanless in 1931 and these studies resulted in the revision and extension of Weller's previous correlations.[9] In the meantime the Pennsylvanian stratigraphic succession exposed along the western border of the Eastern Interior basin had been mapped mainly by Wanless, and in 1932 D. G. Stookey began a similarly detailed study of the lower Pennsylvanian strata in southern Iowa. Later, the Iowa studies were continued and extended by L. M. Cline under the direction of A. C. Tester, and several informal field conferences were held in Iowa by the writers of this paper and M. L. Thompson and A. C. Tester.

As the Iowa field studies progressed, the remarkable similarity of the Pennsylvanian succession east and west of the Mississippi River became increasingly

[1] Published by permission of the chief of the Illinois State Geological Survey and the director of the Iowa Geological Survey. Manuscript received, February 5, 1942.

[2] Illinois State Geological Survey, Urbana, Illinois.

[3] Department of geology, University of Illinois, Urbana, Illinois.

[4] Department of geology, Iowa State College, Ames, Iowa.

[5] The Texas Company, Fort Worth, Texas.

[6] J. M. Weller, "Cyclical Sedimentation of the Pennsylvanian Period and Its Significance," *Jour. Geol.*, Vol. 38 (1930), pp. 108–09.

[7] J. B. Knight, "The Gastropods of the St. Louis, Missouri, Pennsylvanian Outlier: The Pseudozygopleurinae," *Jour. Paleon.*, Vol. 4 (1930), Supplement, pp. 4, 5.
———, "The Location and Areal Extent of the St. Louis Pennsylvanian Outlier," *Amer. Jour. Sci.*, Ser. 5, Vol. 25 (1933), pp. 44, 166–72.

[8] With the aid of a grant from the National Research Council.

[9] H. R. Wanless and J. M. Weller, "Correlation and Extent of Pennsylvanian Cyclothems," *Bull. Geol. Soc. America*, Vol. 48 (1932), pp. 1003–16.

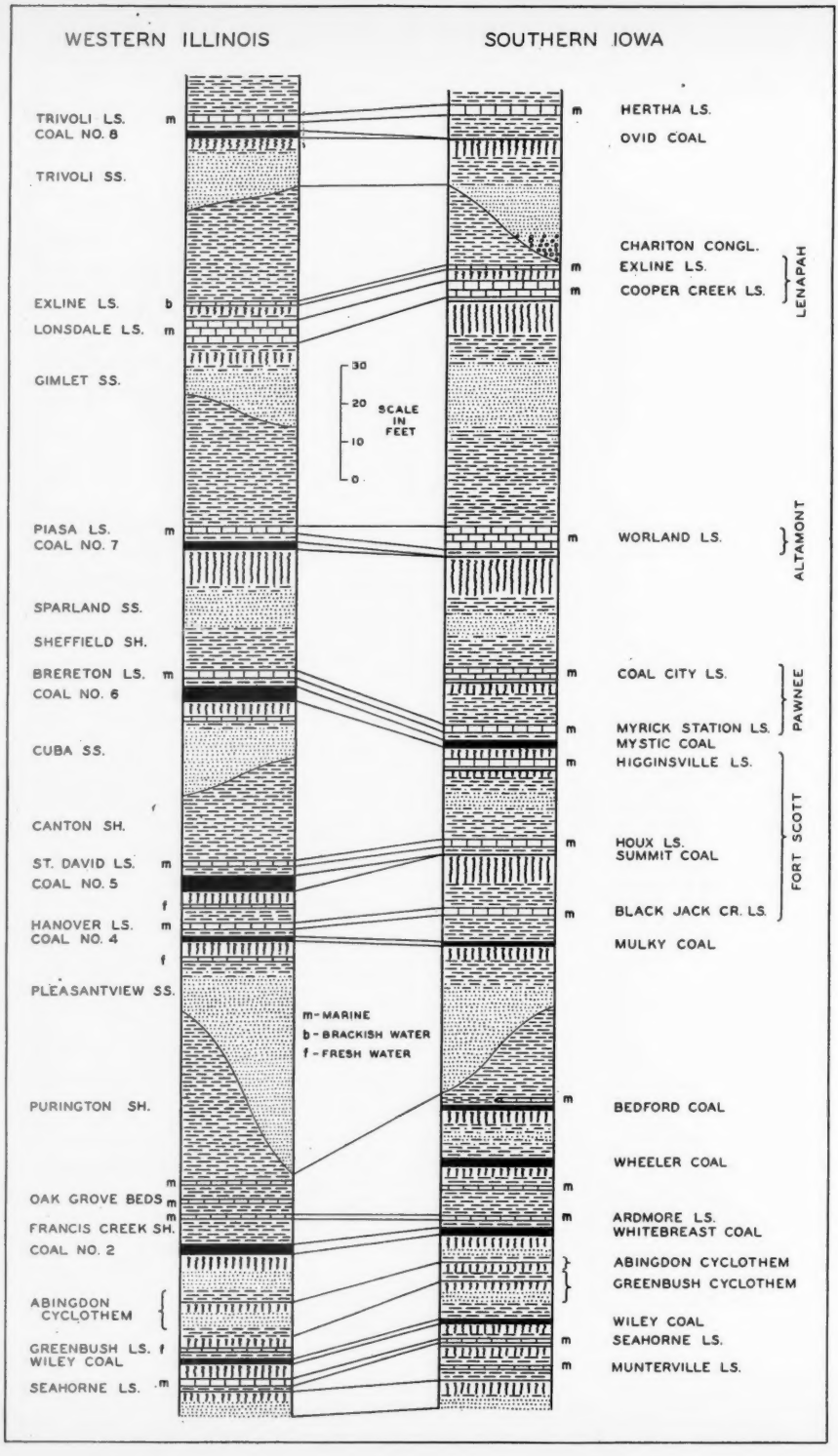


FIG. 1.—Correlation of Pennsylvanian beds in western Illinois and southern Iowa.

apparent, and now that the greater part of the Iowa Pennsylvanian succession has been mapped in detail, the time appears ripe for a thorough review and comparison of the stratigraphic sections in adjacent parts of Iowa and Illinois. Accordingly, a field conference was held early in September, 1941, on which the Illinois Geological Survey was represented by J. M. Weller and H. R. Wanless, and the Iowa Geological Survey was represented by H. G. Hershey and L. M. Cline. Comparable parts of the Pennsylvanian system were studied in Iowa and Illinois, and the correlations of Figure 1 are unanimously approved by the members of this conference. Previously reported tracing and correlation of strata in southern Iowa, northern Missouri, and eastern Kansas[10] by L. M. Cline, F. C. Greene, R. C. Moore, and J. M. Jewett,[11] now make possible the precise recognition of a considerable number of important Pennsylvanian beds from Illinois to the central Mid-Continent region, and other recent investigations with which the writers are not particularly familiar appear to permit the further correlation of some of these beds through Oklahoma and into northern Texas.

CORRELATIONS

The Illinois-Iowa correlations presented here are based on the same types of evidence that have been found useful in the tracing and correlation of beds in the more local stratigraphic studies in these states. They consist of (1) similarity of lithologic peculiarities, (2) similarity of marine faunas, and (3) similarity of position in the stratigraphic succession. Marine limestones are the most conspicuous and important strata for long-range correlation, and the unexampled similarity of most of the correlated limestones in these three respects, together with other supporting evidence, leaves small room for doubt as to their equivalence.

Lower Pennsylvanian strata.—No correlations of the beds comprising the oldest half dozen or more cyclothems of western Illinois with corresponding strata in Iowa are attempted at this time. By agreement with the director of the Iowa Survey, the stratigraphic work of Cline has not been extended below the Munterville cyclothem. A. C. Tester is at present engaged in studies of these lower beds.

Munterville limestone.[12]—The composite nature of the Seahorne "cyclothem" of western Illinois has been recognized for some years. In Iowa two thin but well marked cyclothems are present in this part of the section, and on the basis of their lithological characters, the so-called Seahorne sandstone (the youngest pure white sparkling sandstone) and underclay (exceptionally light-colored, plastic,

[10] L. M. Cline, "Traverse of Upper Des Moines and Lower Missouri Series from Jackson County, Missouri, to Appanoose County, Iowa," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, No. 1 (January, 1941), pp. 23–72.

[11] J. M. Jewett, "Classification of the Marmaton Group, Pennsylvanian, in Kansas," *Geol. Survey Kansas Bull. 38* (1941).

[12] Name proposed by Cline and Stookey.

and comparatively thick) of western Illinois are referred to the lower of these Iowa cyclothems.

The name Munterville is introduced for the lower of these two cyclothems and for the limestone which is its most prominent member. There are numerous outcrops of this limestone and adjacent beds within a radius of $1\frac{1}{2}$ miles of Munterville, Wapello County, Iowa. Good exposures of the Munterville and Seahorne limestones may be seen north and northeast of Munterville in the west-central and north-central parts of Sec. 17, and the south-central part of Sec. 18 in T. 72 N., R. 15 W. The Munterville is particularly well exposed in a northeast-trending ravine a few yards west of the Monroe-Wapello county line and in the NE. $\frac{1}{4}$, SE. $\frac{1}{4}$ of Sec. 13, T. 72 N., R. 16 W.; the locality is in Monroe County, but is not more than $1\frac{1}{4}$ miles west of Munterville.

In the type area this cyclothem comprises, in ascending order: a few inches of fine-grained, cleanly washed white sandstone containing fragments of carbonized wood and prominent fucoidal markings on weathered surfaces; a thick underclay, variegated at some localities; a thin coal; fossiliferous gray shale; a thin fossiliferous green-gray glauconitic marine limestone; and soft thin-bedded blue to green-gray shale, mottled with red, and bearing *Lingula*, discinoid brachiopods, and small pelecypods. From the Munterville limestone and fossiliferous underlying shale, Thompson[13] has described a prolific fusulinid fauna consisting of *Wedekindellina euthysepta* (Henbest)?, *W. dunbari* Thompson, *W. elfina* Thompson, *W. uniformis* Thompson, *Fusulina leei* Skinner, *F. kayi* Thompson, *F.? problematica* Thompson, *F. euryteines* Thompson, and *F. pumila* Thompson. The sandstone member fills an important erosional channel at Redfield in Dallas County, Iowa, and at several places in Warren, Marion, and Monroe counties it cuts out older rocks.

The Munterville limestone is absent in the outcrops of western Illinois except possibly at one locality. It may, however, be equivalent to the Stonefort limestone of southern Illinois which is believed to be slightly older than the Seahorne. This correlation is also suggested by the similarity of the fusulines in the Stonefort and Munterville limestones.

Seahorne limestone.—The Seahorne limestone of Illinois is a comparatively pure, light-colored bed of massive to nodular, brecciated or algal and pseudoseptarian character that is duplicated by similar limestone at a similar position in the Iowa section. This type of limestone in Iowa is associated or continuous with more persistent, evenly bedded, light-colored limestone unknown in Illinois that is crowded with the shells of *Marginifera muricatina* or a closely related species. The Seahorne fauna of small mollusks has not been recognized in Iowa. The local and poorly developed coal horizon immediately below the Seahorne limestone of Illinois is persistent in Iowa and bears thin coal at several places. The greenish shale immediately below the Illinois Seahorne appears to be equivalent to the underclay of this coal.

[13] M. L. Thompson, "The Fusulinids of the Des Moines Series of Iowa," *Univ. Iowa Studies Nat. Hist.*, Vol. 26 (1934), pp. 277–332. Pls. 20–23.

Wiley cyclothem.—This cyclothem is better developed in Iowa than in Illinois. A basal sandstone is rarely present and the prominent underclay rests directly on the Seahorne limestone at many localities in both states. Where the underclay is thickest in Iowa, the Seahorne limestone may be absent or, if present, it is represented by a zone of discontinuous nodules. As in Illinois, the Wiley coal is the best developed and most persistent seam in this part of the section. The coal is succeeded in Iowa by several feet of marine shale, not present or poorly developed in Illinois, that is typically bluish gray with some red mottling and is characterized by thin lenticular sideritic fossiliferous limestone layers that weather to hematite red.

Greenbush cyclothem.—Above the marine shale of the Wiley cyclothem in some of the Iowa outcrops there is an embryonic cyclothem that because of stratigraphic position is correlated with the Greenbush cyclothem of Illinois. The unique and easily recognized fresh-water limestone of western Illinois is absent here, but a thin *Marginifera*-bearing marine limestone has been observed at a few places, and locally about a foot of sandstone forms the base of the cyclothem.

Abingdon cyclothem.[14]—The Abingdon cyclothem (formerly tentatively termed Lower Liverpool) is commonly embryonic and thin, but in western Illinois and Iowa it is persistently present between the Greenbush cyclothem below and the Liverpool cyclothem above. It is exceptionally well developed in parts of southern Knox and northern Fulton counties, Illinois, and is favorably exposed in tributaries of Brush Creek, especially near the center of Sec. 6, T. 9 N., R. 2 E., 4 miles east of Abingdon. In this vicinity the cyclothem includes a basal sandstone, underclay, and a few inches of coal, and gray shale bearing a thin, unpersistent layer of brownish to purplish gray, fine-grained limestone. Elsewhere, however, it is generally very thin and characterized only by a dark streak or coal horizon separating underclay and gray shale, and in most areas it is identified and correlated solely on the basis of its stratigraphic position. Neither a basal sandstone nor a marine limestone is characteristically present, and the most distinctive member of this cyclothem in Iowa is a thin red, platy, almost fissile shale directly above the coal horizon. The Staunton Coal III of Indiana is believed to be referable to the Abingdon cyclothem.

Colchester coal No. 2.—The Colchester coal of Illinois is equivalent to the White Breast coal of Iowa. In each state this seam is the lowest persistent coal that is thick enough to be of any commercial importance. It is Coal IIIa of Indiana and the Tebo coal of northern Missouri. Lower coals that are mined at several places in Illinois and Iowa are very discontinuous and patchy in their development.

Sandstone below the White Breast coal (Isabel sandstone of Illinois) occupied a deep erosional channel near Lovilia, Monroe County, Iowa. Sandstone in similar channels of western Illinois (Browning sandstone) has been correlated with either the Isabel or basal Abingdon sandstone. Because of the stratigraphic position of the Iowa channel, the former correlation is more likely to be correct.

[14] Name proposed by Weller and Wanless.

Ardmore limestone.—The Ardmore or "two-layer" limestone of Iowa is the Bevier "sump rock" of northern Missouri. It consists of two thin gray limestones separated by a thinly laminated dark gray shale bearing *Ambocoelia.* The limestones are abundantly fossiliferous with *Marginifera muricatina* and are believed to be equivalent to the "gray lime" of the Illinois Oak Grove succession of marine beds. In both states the limestone closely overlies the very pimply, black, sheety roof shale of the coal which also in both states locally rises considerably above the coal, because of the presence of the lenticular Francis Creek shale. Other members of the Oak Grove succession have not been certainly recognized in Iowa.

Wheeler and Bedford coals.—Two coals, and apparently two incomplete cyclothems, occur between the Ardmore and Blackjack Creek cyclothems in Iowa. The lower coal, the Wheeler, is the Bevier of northern Missouri and the upper is correlated with the Bedford of that state. Both coals are mined locally in Iowa, in a few places being close enough to be taken in the same entry. No corresponding coals are present in western Illinois although very thin and local seams near Alton and La Salle may be equivalent to one or the other of them. The local occurrence of impure marine limestone above the Bedford coal suggests that these seams may possibly occupy positions within the Oak Grove succession as does the thin coal previously mentioned near La Salle, Illinois.

Pleasantview sandstone.—The Pleasantview sandstone fills the largest and most extensive erosional channels present in the Pennsylvanian succession of western Illinois. Similar sandstone in Iowa likewise fills channels and the unconformity beneath this bed appears to mark one of the most important erosional breaks in the lower part of the Pennsylvanian system; the Iowa Geological Survey places the base of the Henrietta group at this erosional break. The Squirrel sand (subsurface) of the Kansas City region appears to be equivalent to the Pleasantview.

Coal No. 4.—Coal No. 4 is a widespread but thin seam in western Illinois and is similarly developed in Iowa and northern Missouri where it is known as the Mulky coal. Locally it thickens enough to be of some economic value. This is the Lower Fort Scott coal of eastern Kansas.

Hanover limestone.—The Hanover limestone is absent or poorly represented in much of western Illinois but occurs to the south as a persistent bed. In northern Missouri and Iowa, the Black Jack Creek limestone is present at the same position in the section. It is the lower Fort Scott limestone of Kansas. This limestone is characterized by the association of *Marginifera splendens* with *M. muricatina* and it carries the first appearance of the fusuline fauna of which *Fusulina girtyi* is the most important member.

Springfield coal No. 5.—The Springfield coal is the most important seam in western Illinois where it is mined and stripped at many places. In northern Missouri, where it is known as the Summit coal, and in Iowa, it is generally very thin and valueless. No sandstone is present between this and the next underlying seam in western Illinois nor is it typically present in the Iowa section.

St. David limestone.—The St. David limestone is persistent in Illinois and corresponds with the equally persistent Houx limestone of Missouri and Iowa. It is the lower member of the upper Fort Scott limestone of Kansas. *Mesolobus euompygus* occurs more abundantly in this limestone and its associated shales than in any other position in the Pennsylvanian succession.

Higginsville limestone.—No marine equivalent of the Higginsville limestone is present in western Illinois except perhaps at one locality. It is possible that the "fresh-water" limestone below coal No. 6 might grade westward into a marine bed but no evidence that such gradation occurs has been discovered in Illinois. It is more probable that the Higginsville limestone is equivalent to the marine limestone overlying coal 5A of southern Illinois which may extend as far northwest as the Mississippi River bluffs near East St. Louis. In southern Illinois this coal and its associated beds are present in the midst of the interval between coals 5 and 6. The Higginsville is the topmost bed of the Fort Scott limestone of Missouri.

Herrin coal No. 6.—The Herrin seam is the second most persistent commercial coal of Illinois and also is or has been extensively mined in Iowa (Mystic coal) and northern Missouri (Lexington coal). At all these places, as well as at localities where it is too thin to be important, it is marked by three extremely persistent clay partings, one of which is the well known "blue band" of Illinois. It is the opinion of Cline that this seam splits northwestward in Iowa, the split probably occurring at one of the clay partings. In Madison, Dallas, and Guthrie counties, the lower bench is known as the Marshall coal.

Brereton limestone.—The Brereton is one of the widespread limestones of Illinois, and its equivalent, the Myrick Station limestone, is equally persistent in northern Missouri and Iowa. This bed has been correlated with the lower Pawnee limestone of eastern Kansas, but the fact that its fusulines are distinctly different from those present in the upper Pawnee renders this correlation somewhat doubtful. In southern Illinois the Brereton limestone is closely overlain by the Jamestown coal and limestone, both of which thin and disappear to the north. In northern Missouri the upper Pawnee limestone thins, and approaches or joins the lower Pawnee in the Kirksville area so that differentiation is difficult. In Iowa the upper Pawnee may have a counterpart in the Coal City limestone or it may be represented by a zone of limestone nodules bearing large specimens of *Dictyoclostus* and *Composita* immediately overlying the Myrick Station limestone. The position of this zone of nodules and the presence of large fossils suggest that this may be equivalent to the Jamestown limestone of Illinois.

Coal City limestone.—The Coal City (17-foot) limestone of Iowa is unrepresented in western Illinois except possibly at a few places. It is a fine-grained rather massive bed that weathers to a buff color and is the youngest stratum bearing the *Fusulina girtyi* fauna. In all these respects it is similar to the Bankston Fork limestone of southern Illinois and these two beds are correlated with considerable assurance. In some parts of Illinois the Bankston Fork limestone is im-

mediately overlain by the Bankston coal, and the Lonsdale coal of Guthrie County, Iowa, occurs in similar relation to the Coal City limestone. The Coal City limestone is supposed to occur at the stratigraphic position of the upper Pawnee limestone of Kansas but this correlation is uncertain because the fusuline faunas are quite different.

Coal No. 7.—Coal No. 7 in Illinois is a fairly widespread but generally thin seam that overlies an unusually thick underclay. A corresponding coal in Iowa is poorly developed but a very thick underclay likewise occurs at this position in that state. This underclay is probably composite for it appears to be split southward in northern Missouri by the introduction of the Tina limestone which has been correlated with the lower member of the Altamont limestone of Kansas.

Piasa limestone.—The Piasa is a light-colored limestone in part of western Illinois that exhibits the first occurrence of the *Fusulina megista, F. mysticensia* and *F. eximia* fauna. It is almost exactly duplicated by the Worland (50-foot) limestone of Iowa that in turn has been correlated with the upper Altamont limestone of Kansas, although the fusulines suggest that it is equivalent to the Pawnee.

Lonsdale limestone.—The Lonsdale limestone is best developed in western Illinois where it is a thick light-colored more or less nodular and algal bed. All of its peculiar lithological characters are duplicated in the Cooper Creek (Fragmental or Floating rock) limestone of Iowa. In both states a marly zone packed with the tests of *Fusulina eximia* and other species is locally developed at its base. These beds correspond with part of the Lenapah limestone of Kansas.

Exline limestone.—The Exline limestone of Iowa is a thin dark-colored evenly stratified bed occurring close above the Cooper Creek limestone, but separated from it by a coal and underclay. It is the highest limestone of the Des Moines series. A similar bed with meager brackish-water fauna, unnamed but formerly included in the composite Gimlet "cyclothem," is present in the Peoria district of western Illinois. These two beds are believed to be equivalent. The Exline is the "*Trepospira* zone" of Missouri.

Chariton conglomerate.—The Chariton conglomerate is composed largely of limestone pebbles in sand matrix occupying a series of deep erosion channels in Iowa. The important unconformity at its base marks the contact of the Des Moines and Missouri series. The equivalent bed in Illinois is the Trivoli sandstone and it is probably the Wayside (subsurface) sandstone of Missouri. No important channeling at the base of this sandstone has been noted in western Illinois but in the Peoria district limestone conglomerate formerly referred to the Lonsdale limestone may represent the Chariton. Near Springfield, however, the Lonsdale limestone has been cut out by channels filled with Trivoli sandstone and in the subsurface of southern Illinois this bed appears to thicken greatly. Where it rises to the surface in Indiana, it is known as the Inglefield sandstone.

Coal No. 8.—Coal No. 8 is a thin but persistent seam in Illinois. It is probably equivalent to the Ovid coal of Iowa and Missouri.

Trivoli limestone.—The Trivoli limestone is thin and evenly bedded in western Illinois and is similar to the Hertha limestone in its easternmost outcrops in Iowa and Missouri. The Hertha is the earliest *Triticites*-bearing bed and is the lowest limestone of the Missouri series. No fusulines have been noted in the Trivoli limestone but this bed lacks such forms as *Mesolobus* and *Prismopora* which are among the most characteristic Des Moines fossils.

Higher strata.—Outcrops of beds younger than the Trivoli limestone are separated by such distance, and the general nature of their development is so different, that no correlation of these beds can be made without further study.

CONCLUSIONS

Detailed correlations of the principal strata in a Pennsylvanian section nearly 350 feet thick extending from the "Seahorne"-Munterville sandstone to the Trivoli-Hertha limestone in western Illinois and southern Iowa are believed to have been established. The previous recognition of the Des Moines-Missouri contact at the base of the Trivoli sandstone in Illinois, based on paleontological evidence, is substantiated by the stratigraphic sequence.

Correlations for the most part are made for individual beds rather than by cyclothems because it has been recognized for some time that several of the western Illinois cyclothems are composite. It does not necessarily follow, therefore, that because a pair of limestones are equivalent the other corresponding beds of the supposed cyclothems of which they are members are likewise equivalent.

The general development of this part of the Pennsylvanian succession in western Illinois and southern Iowa is quite similar. It is evident, however, that marine environments were relatively somewhat more important in Iowa, where several marine limestones occur that are absent or poorly represented in western Illinois. Conversely, non-marine environments were more important in Illinois as is shown by the thicker and more widespread coals, the presence of bedded freshwater limestones and the more common occurrence of channel-filling sandstones.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 26, NO. 10 (OCTOBER, 1942), PP. 1594-1607, 8 FIGS.

LATERAL VARIATION IN CHESTER SANDSTONES PRODUCING OIL AND GAS IN LOWER WABASH RIVER AREA, WITH SPECIAL REFERENCE TO NEW HARMONY FIELD, ILLINOIS AND INDIANA[1]

GEORGE V. COHEE[2]
Indianapolis, Indiana

ABSTRACT

Much oil is produced in the region of the lower Wabash River which is the boundary between Illinois and Indiana in this area. Oil and gas are produced from lower Pennsylvanian and Chester (upper Mississippian) sandstones and from the Fredonia limestone (McClosky "lime") of the Ste. Genevieve formation (lower Mississippian series). The oil fields occur along a broad slightly folded anticline that roughly parallels the course of the river. The areal distribution of the oil pools is different for each producing formation and appears to be controlled to a greater degree by lensing sand conditions than by structure.

Oil and gas in the Wabash River valley in southeastern Illinois and southwestern Indiana are produced from lower Pennsylvanian and Chester sandstones and the Fredonia limestone (McClosky "lime") of the Ste. Genevieve formation. The principal fields in the area are New Harmony and Keensburg. These include an almost continuous producing area from Keensburg, Wabash County, Illinois, at the north, to the south side of Ribeyre Island, 3 miles southwest of New Harmony, Indiana (Fig. 1). This single area is approximately 18 miles long and varies in width from $\frac{1}{2}$ mile to more than 2 miles at its widest point in White County, Illinois. On January 1, 1942, there were almost 1,000 producing wells in the two fields, and the productive area proved by drilling was 7,238 acres.

The fields along Wabash River in Wabash County and northeastern White County, Illinois, occur along a broad slightly folded anticline that roughly parallels the course of the river. Oil and gas along the anticline in general occur in local "highs" but the productive area of individual sands is more dependent on the sand characteristics than on structure. Most of the Chester sands in this area are very lenticular and considerable variation in thickness is noted from one well to another.

All of the eight Chester sandstone formations and additional sandstone beds in other Chester formations were found productive in one place or another throughout the area.

The rock strata comprising the Chester series in the lower Wabash River area are approximately 1,100 feet thick and are overlain by 1,800 feet of Pennsylvanian beds. The entire Chester sequence is present in part of the south half of the New Harmony field, but northward and into Wabash County the uppermost beds have been truncated by pre-Pennsylvanian erosion. In northern Wabash

[1] Read in part before the Association at Denver, April 24, 1942. Manuscript received, July 25, 1942. Published with permission of the chief of the Illinois State Geological Survey, Urbana, Illinois.

[2] Assistant state geologist, Division of Geology. Department of Conservation, Indiana. Formerly assistant geologist, Illinois State Geological Survey, Urbana.

County there are 700 feet of Chester beds topped by the Menard formation which is directly overlain by Pennsylvanian strata; the Kinkaid, Degonia, Clore, and Palestine formations are absent. In addition to the truncation of the upper beds there is slight thinning of the formations northward.

The area considered in detail in the present paper is the New Harmony field. The field was discovered by the Superior Oil Company's New Harmony Realty

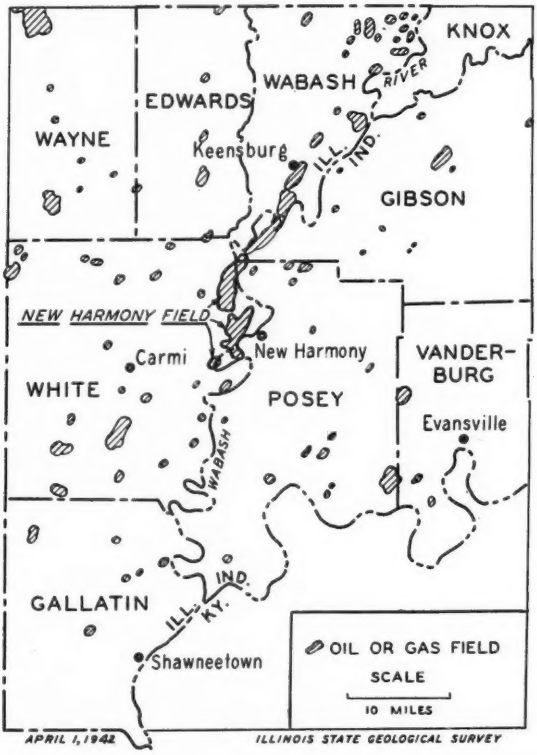


FIG. 1.—Location of New Harmony field in lower Wabash River area.

Corporation well No. 1, Sec. 5, T. 5 S., R. 14 W., Posey County, Indiana, at the south end of the present field. The well was completed, June, 1939, in the Waltersburg sandstone with initial production of 252 barrels a day flowing after testing the McClosky "lime." The field was rapidly developed, and by the end of 1941 it included a productive area of 5,000 acres in which there were 647 producing wells. The total production of crude oil at that time was 11,700,000 barrels, and the future reserves were estimated to be more than 20 million barrels.

Production in the field is principally from Chester sandstones that occur in irregular areas, and no one sand is productive throughout the field. The McClosky "lime" of lower Mississippian age is productive in some parts of the field, and the basal Pennsylvanian sandstone is productive in a small area.

As developed at present, the Bethel sandstone is productive over the largest area, approximately 3,300 acres; the Aux Vases sandstone is next with a productive area of 2,640 acres; and the Cypress sandstone is third with 2,000 acres. The area of Waltersburg, Tar Springs, and Paint Creek-Bethel[3] sandstone production is 750, 480, and 440 acres, respectively. There is a total of 9,610 acres of Chester sand production in the field. The average thickness of "pay" ranges from 15 to 25 feet.

A summary sample study log[4] of a representative well in the New Harmony field lists the following strata penetrated.

System, Series, or Formation	*Thickness (Feet)*	*Depth (Feet)*
No samples	130	130
Pennsylvanian system	1,695	1,825
Mississippian system		
Chester series		
Kinkaid limestone and shale	35	1,860
Degonia sandstone	15	1,875
Clore shale, sandstone, and limestone	55	1,930
Palestine sandstone and shale	80	2,010
Menard limestone and shale	130	2,140
Waltersburg sandstone and shale	25	2,165
Vienna shale and limestone	40	2,205
Tar Springs sandstone	135	2,340
Glen Dean limestone	50	2,390
Hardinsburg sandstone and shale	20	2,410
Golconda limestone and shale	205	2,615
Cypress sandstone	35	2,650
Paint Creek limestone and shale	80	2,730
Bethel sandstone	70	2,800
Renault limestone and shale (includes so-called Aux Vases limestone)	55	2,855
Aux Vases sandstone	25	2,880
Iowa series		
Ste. Genevieve formation	145	3,025
St. Louis limestone	49	3,074

STRUCTURE

Contours are drawn on the base of the basal Golconda limestone, a thin uniform limestone occurring throughout the field.

Structurally, the New Harmony field is apparently comprised of two anticlines, both trending northeast and southwest (Fig. 2). Two small domes with 10 to 20 feet of closure are present in the north half of the field and several irregular structures with closures up to 30 feet occur in the south half of the field.

Away from the field the rock strata dip gently eastward whereas westward the

[3] Some of the production reported to be from the Paint Creek sandstone in the north part of the field may be from the Bethel sandstone. Sufficient well data were not available in the particular area in question to establish the correlation.

[4] Samples studied by F. E. Tippie, Illinois State Geological Survey.

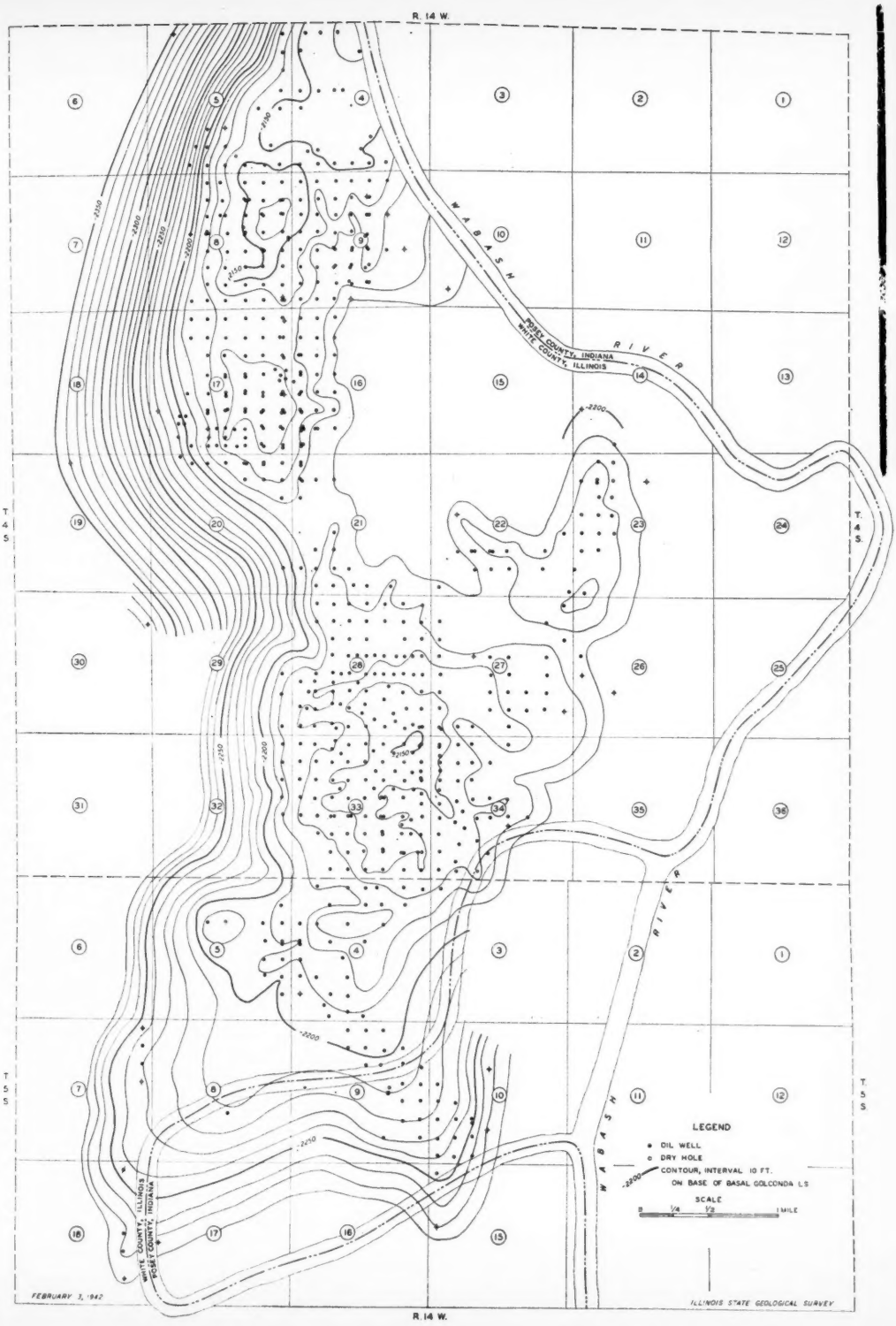


FIG. 2.—Structure map of New Harmony field. Contours on base of basal Golconda limestone.

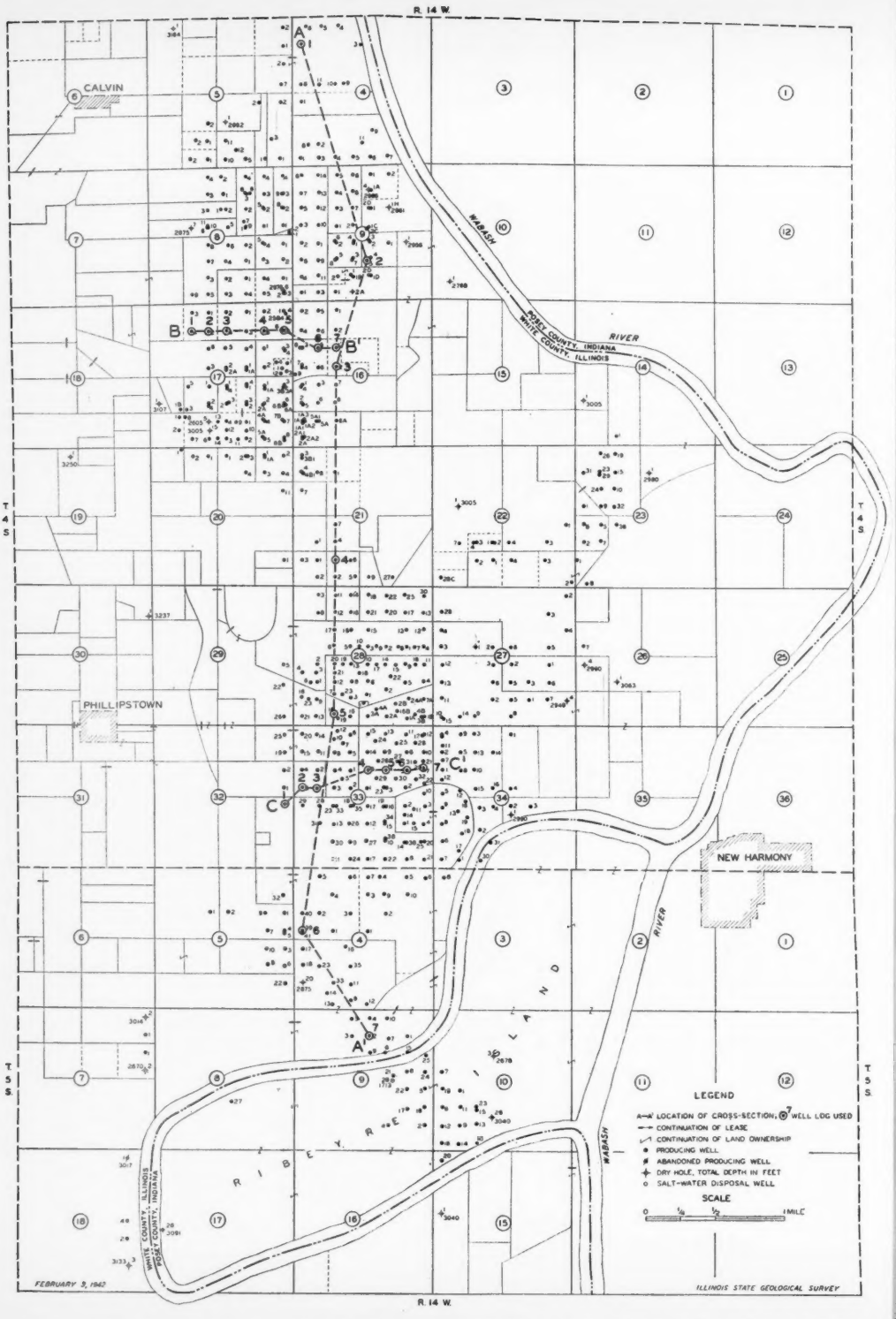


FIG. 3.—New Harmony field (consolidated), White County, Illinois, and Posey County, Indiana, showing location of electric-log cross sections.

dip is at the rate of 160 feet per mile. This is comparable to the amount of dip on the west side of the LaSalle anticline in certain areas.

ELECTRIC-LOG CROSS SECTIONS

Three electric-log cross sections in the New Harmony field were prepared: section *AA'* north and south, *BB'* east and west across the north half of the pool, and *CC'* east and west across the south half of the pool (Fig. 3). Correlation of the Chester producing sands in the field is shown for each well.

In section *AA'*, which extends north and south through the field, the wells whose records have been used average from a mile to 1½ miles apart (Fig. 4). The total distance represented by the cross section is 7 miles. The log of well 7 is a sample study adjusted to the electric log of the well.

Considerable variation is noted in the sandstones of the Clore and Palestine formations. The Waltersburg formation is mostly shale in well 1, but it becomes more sandy southward and in well 4 it is a fairly well developed sand. Farther southward, in wells 5 and 6 it is again more shaly, and in well 7, in the extreme south end of the field, it is again a fairly well developed sand. The Tar Springs formation in well 1 is a well developed sand at its base, with alternating shale and sandstone in the upper part of the formation. The formation thickens southward and in well 4 shale is present in the lower part. It becomes a uniform sand body in the area of well 5, but in well 6 the entire formation consists of sandstone lenses and shale.

The sandstone in the Cypress formation is thin and poorly developed in wells 1 and 2 in the north part of the field but is thicker and more uniform southward to the extreme south end of the field, where it becomes somewhat shaly.

The sandstone member of the Paint Creek is fairly well developed in the area of well 2, in the north half of the field, but is predominantly shale in the south part of the field.

Bethel sandstone is poorly developed in well 1 in the extreme north end of the field but is better developed southward. The Aux Vases sandstone shows little variation in character in the cross section. The low resistivity curve on the electric log ordinarily shown by the sandstone, even where it is well saturated with oil, is thought to be due to the high content of connate water.[5] Variation in the area of production of the sand is largely due to the varying amounts of calcium carbonate cementing material.

Cross section *BB'* extends from west to east across the north half of the New Harmony field, which is one mile wide at this point (Fig. 5). Most of the wells are one location (660 feet) apart, and the greatest distance between any two wells is approximately ¼ mile.

The Kinkaid limestone has been truncated on the higher part of the structure and is present only on the east side. There is considerable variation in the uppermost Chester sandstones from west to east across the field in the area of the cross

[5] Everett F. Stratton, Schlumberger Well Surveying Corporation, personal communication.

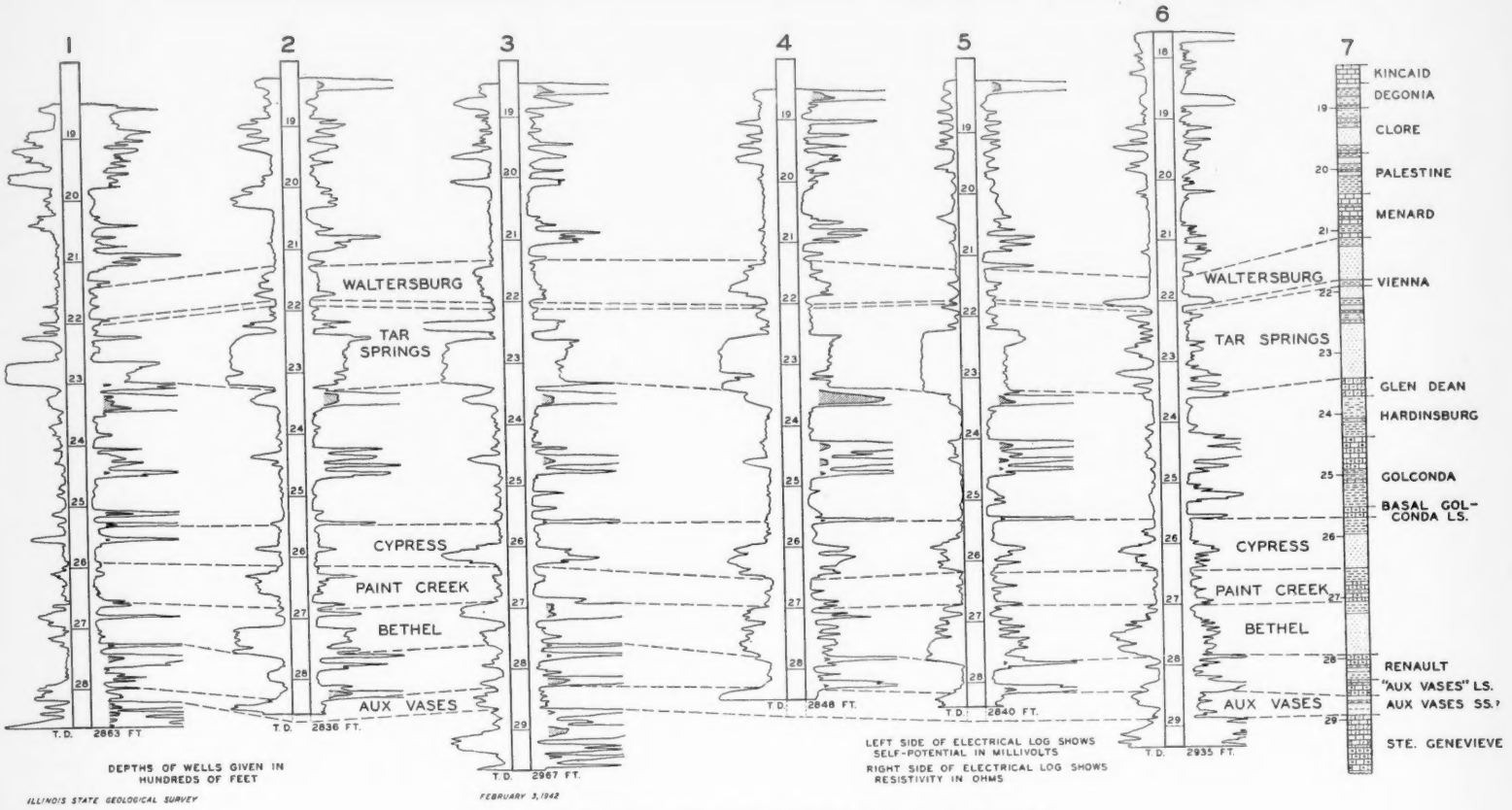


FIG. 4.—New Harmony field, north-south electric-log cross section *AA'*.

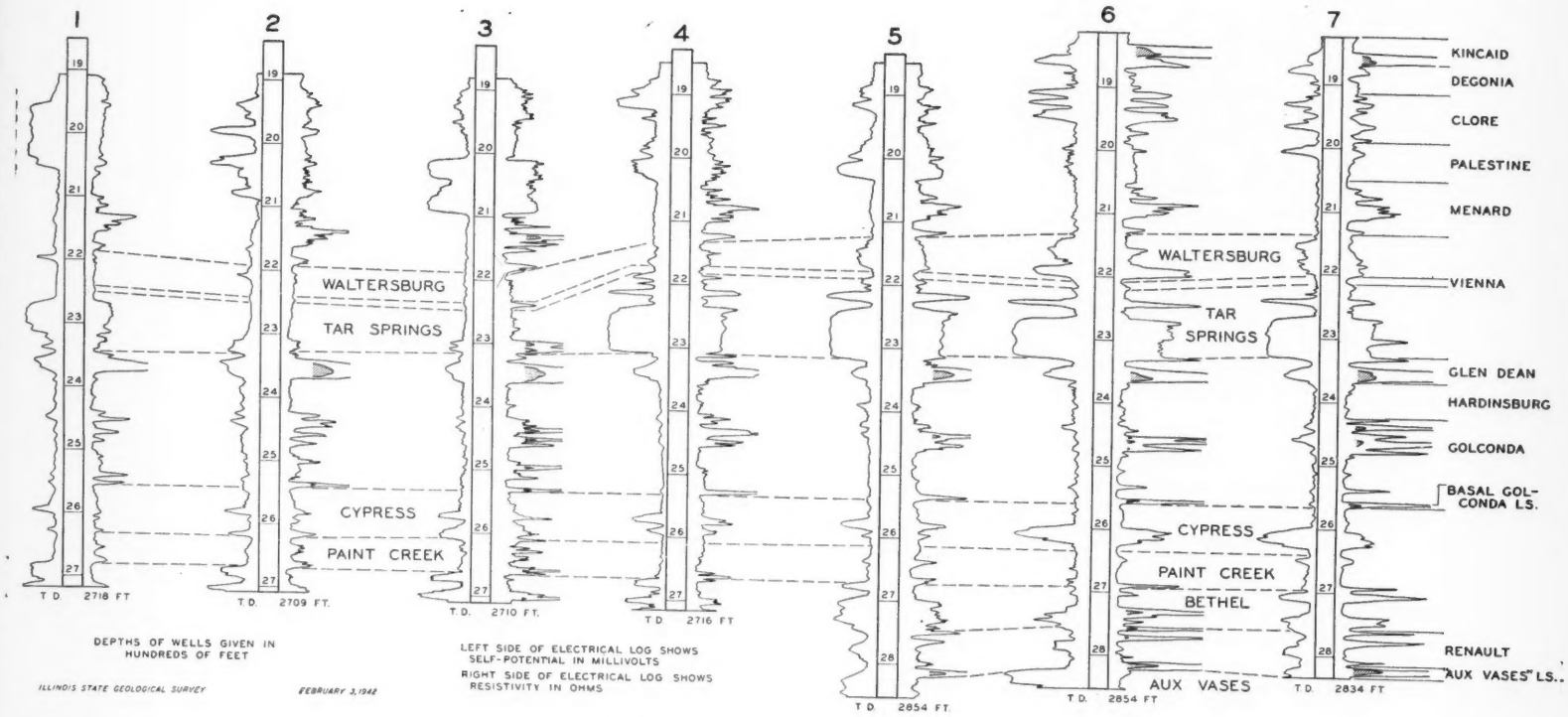


FIG. 5.—New Harmony field, west-east electric-log cross section *BB'*.

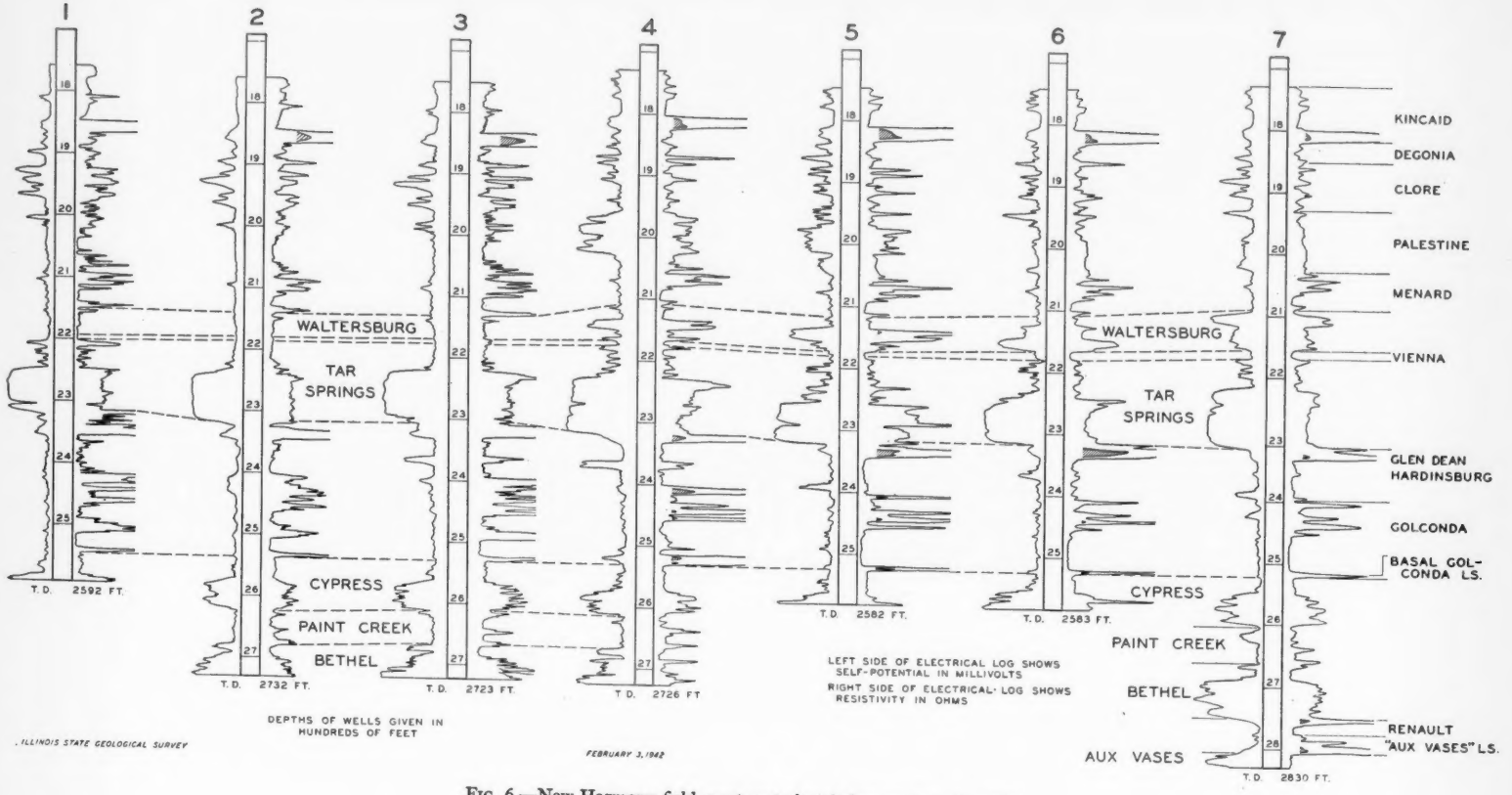


FIG. 6.—New Harmony field, west-east electric-log cross section *CC'*.

section. The Palestine sandstone is poorly developed in wells 6 and 7 on the east side but thickens westward with some lithologic variation, and on the west side of the field in well 1 it is in contact with the overlying sandstone member of the Clore, making a continuous sand body 100 feet thick.

The Waltersburg sandstone is fairly well developed in well 6 on the east side of the field but in other wells of the cross section it is predominantly shale.

The Tar Springs sandstone is very thin in wells 2 and 3 but is a thick sand body in wells 4, 5, 6, and 7.

The Cypress sandstone thickens and becomes a more uniform sand body from west to east. The Paint Creek formation is somewhat sandy in part of the area but in general it is principally shale with some lenticular sand bodies. The Bethel sandstone shows variation in thickness in both the upper and lower beds which are separated by shale.

Cross section *CC'* extends from west to east across the south half of the New Harmony field (Fig. 6). The length of the section is one mile. All wells are approximately one location (660 feet) apart, except that wells 3 and 4 are slightly more than $\frac{1}{4}$ mile apart.

The Palestine sandstone is thin and poorly represented in wells 6 and 7 on the structure. In wells 4 and 5, which are as high structurally as wells 6 and 7, the sandstone is well developed but contains water.

The Waltersburg sandstone is fairly well developed in wells 4, 5, 6, and 7, particularly in well 7, but on the west edge of the field the formation is almost entirely shale.

The Tar Springs sandstone shows some variation in thickness in the area of the cross section. The sandstone in the Hardinsburg formation is poorly developed in wells 1 and 2 but becomes better developed in wells 3, 4, 5, and 7.

The Cypress sandstone is fairly uniform in character.

PRODUCTIVE AREAS OF SANDSTONES

Waltersburg sandstone production has been limited to the south half of the field and occurs in rather small irregular areas as a result of the lenticular character of the sand (Fig. 7).

Tar Springs production occurs in the thin lenticular sand body at the top of the formation which is present in small areas in both the north and south parts of the field. The massive sandstone below ordinarily contains much water in this area. Although there are considerable variations in the sand, it is a well developed sand body in most of the field (Fig. 7).

Cypress production is limited in the north half of the field but includes a fairly large area in the south half where the sand is more fully developed (Fig. 7).

The Paint Creek-Bethel sandstone production is limited to the north half of the field where the sand is best developed. The formation thins southward and becomes shaly in the south half of the pool (Fig. 8).

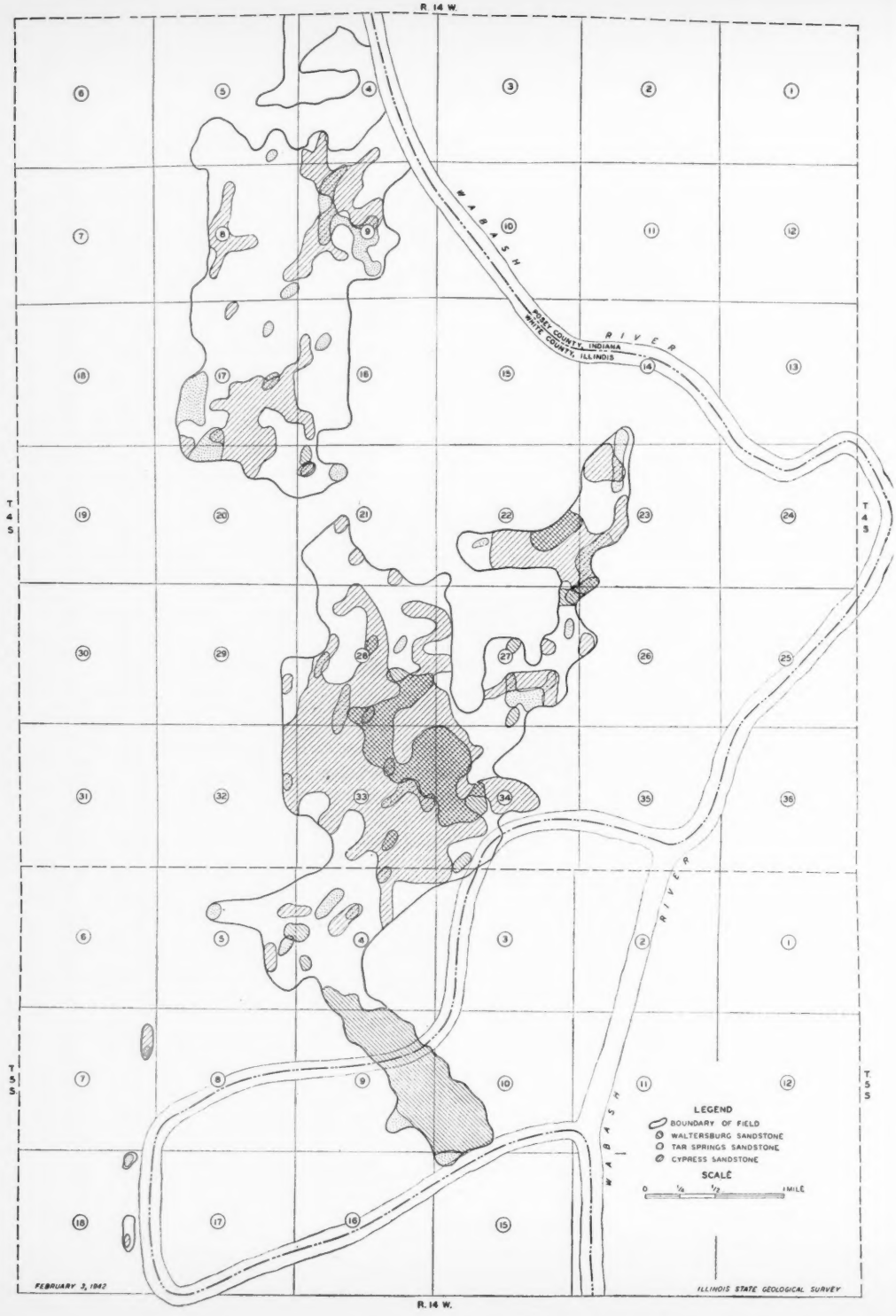


FIG. 7.—Areas of present production and reported saturation of Waltersburg, Tar Springs, and Cypress sandstones in New Harmony field.

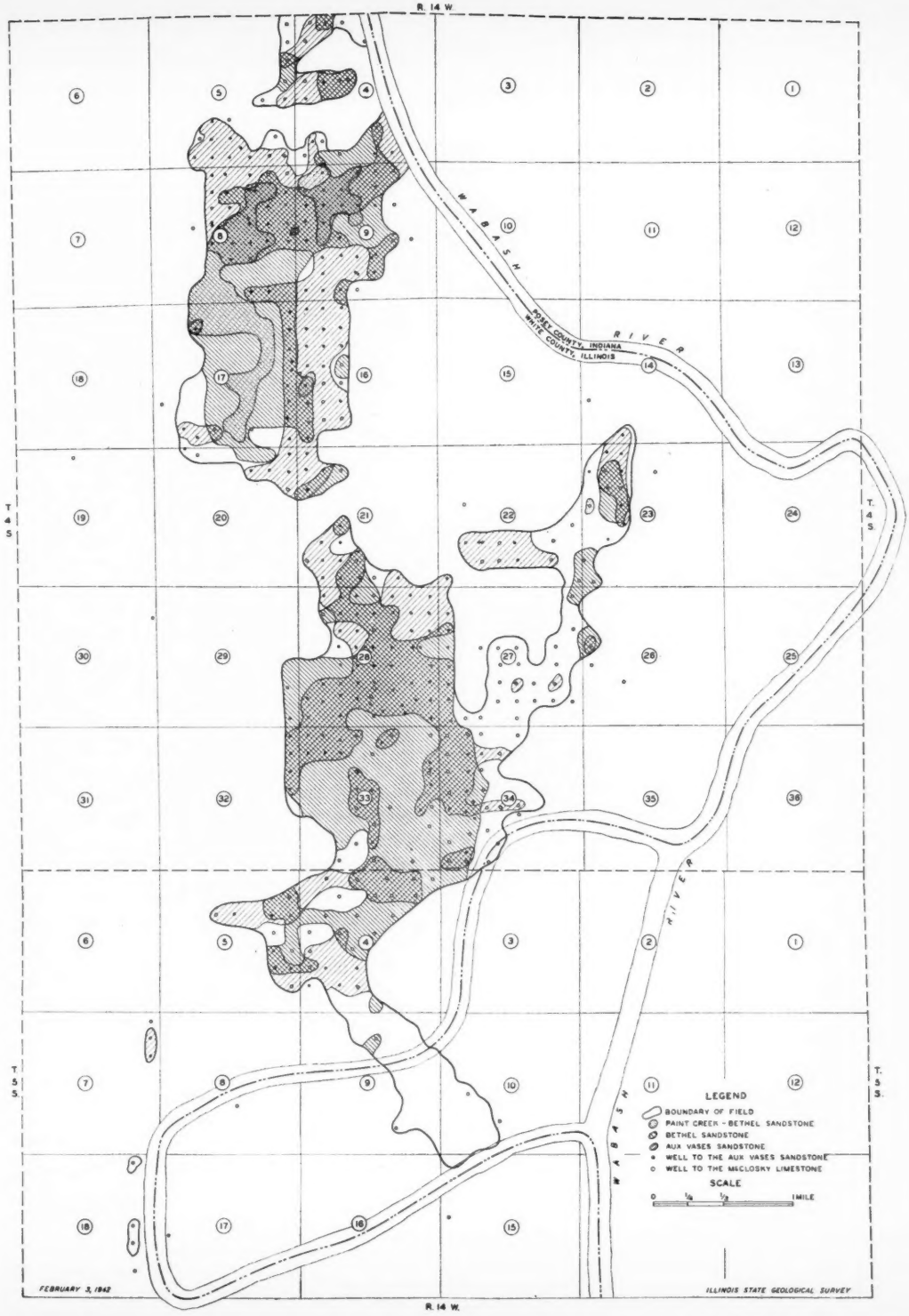


FIG. 8.—Areas of present production and reported saturation of Paint Creek-Bethel, Bethel, and Aux Vases sandstones in New Harmony field.

Bethel sandstone production occurs in irregular areas in both the north and south parts of the New Harmony field (Fig. 8).

Aux Vases production, like the Bethel, includes a large area in each part of the field. Irregularity of the producing area is largely due to the calcareous character of the sand (Fig. 8).

LITHOLOGY OF SANDSTONES WITH REFERENCE TO OIL PRODUCTION

Core studies of the producing Chester sands in the New Harmony field show that the sands are fine-grained to very fine-grained and vary from massive to thin-bedded sand bodies with numerous shale partings. The cementing material is generally silica but calcareous cement was noted in some of the cores. The Aux Vases sandstone differs from the other Chester sandstones in its calcareous content. The fine quartz grains are cemented with a varying amount of calcium carbonate throughout the field. In some areas in the field the amount of calcium carbonate is so great that the sand is not porous or permeable enough to produce. It is customary practice to shoot the sand with nitroglycerine, and in the south part of the field some of the Aux Vases sand wells were shot with 600 or more quarts of nitroglycerine.

Subsurface studies in southern White County south of the New Harmony field and in Gallatin County suggest that the sandstone which is called Aux Vases in the New Harmony field is the Rosiclare sandstone in subsurface studies of Hardin County. According to this correlation the limestone called Aux Vases may be the Levias limestone of Hardin County.

NEAR-SHORE DEPOSITION OF RECENT SEDIMENTS

Studies of continental shelf sediments aid in the interpretation of conditions of deposition during geologic time. A study of the sediments of Santa Monica Bay off the coast of California revealed that areas of silt and sand, fine sand, sand and gravel, and rocky bottom all occur within a mile from shore and within a depth of 10 fathoms.[6] Similar irregularity in the character of the sediments was found throughout the bay. However, near shore, in depths of a few fathoms, the sediment is on the average just as fine as that far out on the shelf.

Cores which were taken approximately 2,000 feet from shore and in 25 feet of water and which penetrated into the bottom 22–25 feet showed stratification of the sediments. The upper 3–12 feet of the cores were silt and fine sand, becoming finer with depth. Below this layer was sand of variable thickness and coarseness. Two cores had gravel beds at an appreciable depth. The layers were somewhat lens-shaped. There appears to be no general regularity of deposition, either laterally or vertically.

[6] F. P. Shepard and G. A. MacDonald, "Sediments of Santa Monica Bay, California," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22, No. 2 (February, 1938), pp. 201–16.

DEPOSITION OF CHESTER SANDSTONES

According to what is known about the character and distribution of recent sediments on the continental shelf, the lithologic variation of the Chester sandstones in the New Harmony field indicates that they were deposited near shore in advancing Chester seas. As the sandstones are generally composed of very fine to fine sand grains, the writer is of the opinion that the sediments were supplied by a relatively low land mass traversed by large streams having low gradients. Sedimentation involved current action and wave action, which affected distribution of the sediments as they were carried in, and reworked unconsolidated alluvial[7] sediments already deposited. Under such conditions sand bars[8] undoubtedly developed and other irregular sand bodies were deposited. These deposits may or may not have remained as deposited, depending on the depth of the wave action and variation of the currents. As the sea advanced farther inland the sand deposits became more stable and finally were covered and preserved by later sediments. After compaction and consolidation of the sediments, the resulting rock strata were lenticular or more probably disc-shaped[9] sand bodies that graded laterally into siltstone or shale, or were "sheet sands" that varied considerably in character.

Where the Tar Springs formation is predominantly shale there is a thinning of the interval between the Menard and Glen Dean limestones. Where the Vienna limestone is present the same thinning is observed between it and the Glen Dean limestone. This thinning of interval, the greatest of which amounts to approximately 18 per cent, is probably due to non-deposition and greater compaction of the Tar Springs sediments where they are principally shale.

The variable reservoir conditions found in the Chester sandstones in the lower Wabash Valley area make successful drilling within the fields uncertain. As a guide to further exploration within the area of development, it is suggested that isopach maps should be prepared for each producing sand to determine the extent and variation of the sand body in addition to lithologic studies of the cores and the study of water conditions within the reservoir.

ACKNOWLEDGMENTS

The study was made possible by the electrical logs and other data furnished by the various oil companies having wells in the area. Their assistance is greatly appreciated. The writer is grateful to members of the Survey staff for helpful suggestions in the study.

[7] J. Marvin Weller and A. H. Sutton, "Mississippian Border of Eastern Interior Basin," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 5 (May, 1940), p. 847.

[8] Charles Brewer, Jr., "Genetic Relationship of Oil Reservoirs to Shoreline Deposits," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 6 (June, 1928), p. 600.

[9] Charles Brewer, Jr., *op. cit.*, p. 604.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 26, NO. 10 (OCTOBER, 1942), PP. 1608–1631, 8 FIGS.

CROCKER FLAT LANDSLIDE AREA, TEMBLOR RANGE, CALIFORNIA[1]

RUSSELL R. SIMONSON[2] AND MAX L. KRUEGER[3]
Los Angeles and North Hollywood, California

ABSTRACT

The Crocker Flat landslide, located in the vicinity of Recruit Pass and northwest of Fellows, is composed largely of lower Miocene and Oligocene sands and silts and a minor amount of middle Miocene shale which were superimposed upon, and subsequently infolded with, younger Miocene sediments. This landslid mass descended by gravity, in upper Miocene time, from a highland located within or west of the San Andreas Fault zone, prior to the deposition of the Santa Margarita (upper Miocene). During Santa Margarita time coarse clastics derived from crystalline rock masses west of the Temblor Range were deposited unconformably over the Crocker Flat landslide and adjacent areas. The Santa Margarita beds and the Crocker Flat landslid mass were involved in the post-Miocene orogeny which elevated the Temblor Range and folded and faulted both of these units. Infolded and downfaulted outliers of Santa Margarita, on top of the Range, have been preserved from later erosion.

On the summit of the Range clastics so coarse that they have been mapped as "Basement complex" by several workers are considered to be Santa Margarita in age because they are intertongued with and grade laterally into sands and boulder beds containing Santa Margarita fossils in adjacent areas. Furthermore a portion of the landslid lower Miocene and Oligocene sediments of the Crocker Flat area are unconformable beneath these coarse clastics. This relationship also tends to preclude the premise of this so-called "basement" being a part of a huge overthrust sheet.

The crystalline rocks previously mapped as "Basement complex" on the west side of the Range are not in place but are detrital in origin and of Santa Margarita age also; these sediments owe their coarseness to a proximity of source and to possible minor landsliding during deposition.

The intercalated lenses of granitoid and schistose boulders and sands in the upper Miocene punky shales on the northeast side of the Temblor Range are equivalent in age to the coarse Santa Margarita conglomerates on the southwest side of the Range. These beds are believed to have had a common western source which must have been near at hand, within or west of the San Andreas Fault zone. The erosional remnants of Santa Margarita conglomerate along the summit and higher parts of the Temblor Range are regarded as being normally depositional in origin and not *klippen* remnants of an overthrust sheet; these deposits represent an intermediate facies between the interbedded conglomerate and punky diatomaceous Santa Margarita on the northeast and the coarse conglomerates on the southwest side of the Range.

The Recruit Pass fault is a normal fault with its western side downthrown; it is thought to be one of the lines along which uplift occurred to give the present elevation of the Temblor Range.

ACKNOWLEDGMENTS

The writers are indebted to E. B. Noble, chief geologist, Union Oil Company of California, for permission to publish this paper. To W. F. Barbat of the Standard Oil Company of California grateful acknowledgment is given for certain helpful criticism and the use of his macrofossils from the Crocker Flat area. To Glenn C. Ferguson, division paleontologist of the Union Oil Company at Bakersfield, the writers are deeply indebted for exacting microfossil age correlations from the many surface samples collected; without information furnished by Mr. Ferguson and his assistant, Aden Hughes, many of the conclusions of this paper would be untenable.

[1] Read before the Pacific Section of the Association at Los Angeles, October 17, 1941. Manuscript received, May 9, 1942.

[2] Geologist, Ohio Oil Co., 437 S. Hill St., Los Angeles, Calif.

[3] Chief of field parties, Union Oil Company of California.

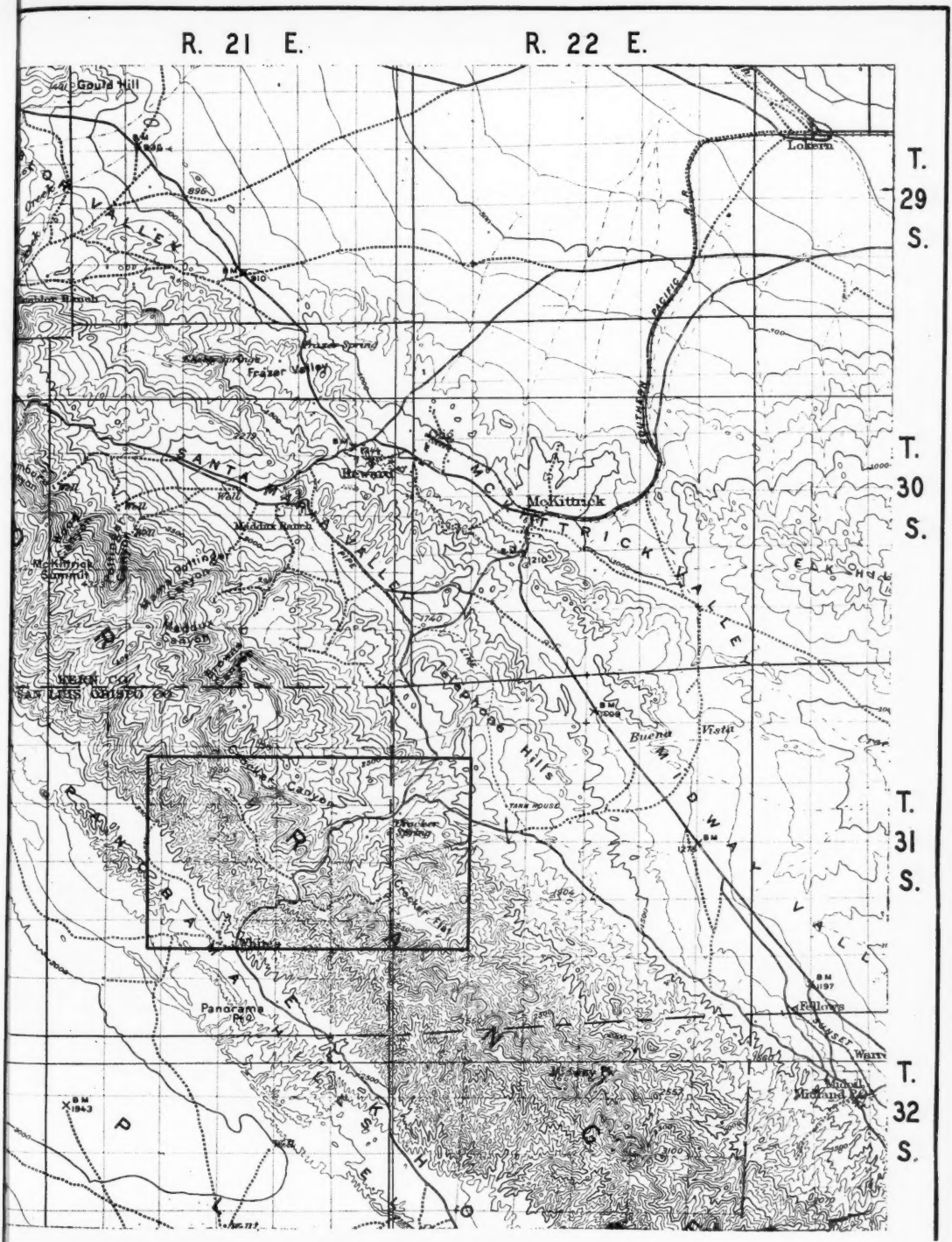


FIG. 1.—Index map showing area of geologic map (Fig. 8). Topographic contour interval, 100 feet.
United States Geological Survey.

Sincere thanks are due M. N. Bramlette, James Gilluly, H. W. Hoots, Harry R. Johnson, and N. L. Taliaferro for helpful criticism of the manuscript.

INTRODUCTION

There exists, in the Crocker Flat-Recruit Pass area of the Temblor Range, a small locality which exhibits one of the most intricate and diverse geological problems in California. Here, to all appearances, crystalline rocks overlie lower Miocene sediments with an almost horizontal contact, and lower Miocene sediments rest on upper Miocene siliceous shales with a discordant contact varying in dip from less than 10° to 90°. A cursory geological examination of the area leaves one confused and somewhat bewildered. Arnold and Johnson (1)[4] early realized the confusing geological relationships in this locality when, in U. S. Geological Survey *Bulletin 406* they failed to describe these crystalline rocks under the heading of "Stratigraphy" and only mentioned them briefly under the heading of the "McKittrick formation" on page 87, as follows:

> Here gravels and sands believed to belong to the McKittrick formation are involved in the intense faulting which has pushed a small block of pre-Cretaceous granite up through all the overlying sedimentary beds and brought it into contact with late Miocene deposits at the summit of the range.

Two small areas of "basement rocks" are, however, clearly shown on their geologic map (Plate 1), and in these localities their McKittrick formation is shown to be resting unconformably on "schists and other metamorphics associated with granites (Sgr)."

At the 1940 meeting of the Pacific Section of the American Association of Petroleum Geologists, F. S. Hudson and G. H. White (2) presented an excellent paper on this area; this paper advanced the concept that these exceptional relationships should be explained by a large low-angle overthrust sheet, the Recruit Pass fault. This fault is thought, by them, to override the Temblor Range from the west, carrying in basement crystallines and Oligocene and Santa Margarita sediments, from a province west of and without the Temblor Range. Their concept includes also the subsequent folding of this low-angle thrust plate in late Miocene time. They further suggested that the materials of the "fanglomerate lenses" in the Santa Margarita diatomaceous shale, on the northeast side in the Range, were derived from crystalline rocks which had been thrust over the Temblor Range into the area tributary to upper Miocene shale deposition.

Other writers have mentioned these occurrences of granitoid and schistose material but none, excepting Hudson and White, has given a detailed explanation of their origin. All have expressed surprise at its apparent existence on the northeast side of the San Andreas Fault zone in contradiction to the generally accepted concept that between the southern end of the Carrizo Plains and San Francisco

[4] Numbers indicate references at end of paper.

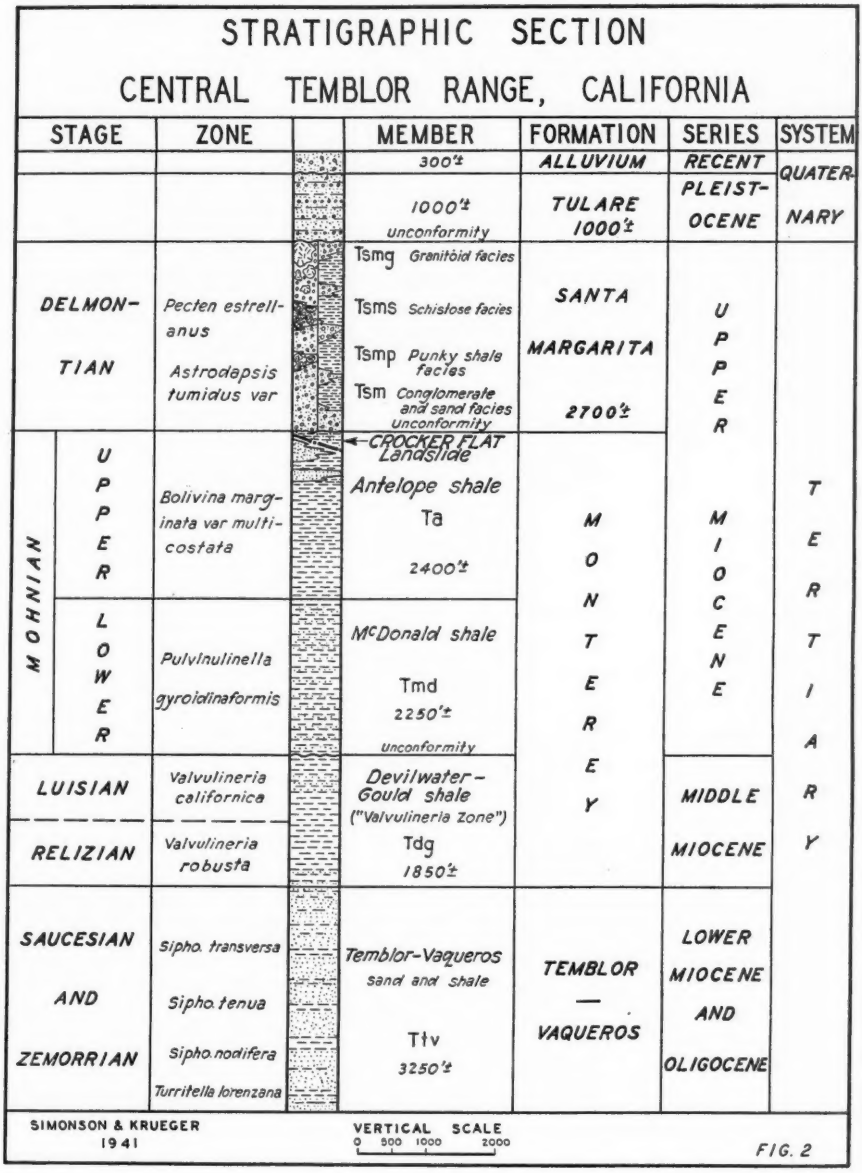

STRATIGRAPHIC SECTION
CENTRAL TEMBLOR RANGE, CALIFORNIA
STAGE
ZONE
MEMBER
FORMATION
SERIES
SYSTEM
300'±
ALLUVIUM
RECENT
QUATER-
1000'±
unconformity
TULARE
1000'±
PLEIST-
OCENE
NARY
DELMON-
TIAN
Pecten estrell-
anus
Astrodapsis
tumidus var
Tsmg Granitoid facies
Tsms Schistose facies
Tsmp Punky shale facies
Tsm Conglomerate and sand facies
unconformity
SANTA
MARGARITA
2700'±
U
P
P
E
R
CROCKER FLAT
Landslide
MOHNIAN
U
P
P
E
R
Bolivina marg-
inata var multi-
costata
Antelope shale
Ta
2400'±
M
O
N
T
E
R
E
Y
M
I
O
C
E
N
E
T
E
R
T
I
A
R
Y
L
O
W
E
R
Pulvinulinella
gyroidinaformis
McDonald shale
Tmd
2250'±
unconformity
LUISIAN
Valvulineria
californica
Devilwater-
Gould shale
("Valvulineria Zone")
Tdg
1850'±
MIDDLE
MIOCENE
RELIZIAN
Valvulineria
robusta
SAUCESIAN
AND
ZEMORRIAN
Sipho. transversa
Sipho. tenua
Sipho. nodifera
Turritella lorenzana
Temblor-Vaqueros
sand and shale
Ttv
3250'±
TEMBLOR
—
VAQUEROS
LOWER
MIOCENE
AND
OLIGOCENE
SIMONSON & KRUEGER
1941
VERTICAL SCALE
0 500 1000 2000
FIG. 2

FIG. 2

Bay the basement rocks on the northeast side of the San Andreas Fault zone consist entirely of serpentine and altered sediments known as "Franciscan." Basement rocks on the southwest side of the San Andreas fault are consistently batholitic granitoid rocks (Santa Lucia) (3) with associated inclusions of schists, marbles, and other metamorphics (Sur series). (3).

Although the writers' work in this area had not been completed and their ideas not entirely crystallized, it was apparent in 1940 that they disagreed with Hudson and White on certain points in regard to age assignments, correlations, and structural history. The writers are fortunate to have had the opportunity to map this area in detail during the past year and to extend their mapping many miles north, south, and east of this locality. Special emphasis has been placed, during this work, on the collecting of surface samples in all critical localities so that interpretations and age correlations could be closely tied, micropaleontologically, into the type stratigraphic section as recognized for the Temblor Range area. More than 150 samples were collected in the area covered by Figure 8 of this paper and of these, approximately 70 samples contained diagnostic foraminiferal assemblages which permitted definite age assignments.

STRATIGRAPHY

GENERAL

The general structure of this part of the Temblor Range is that of a faulted anticlinorium. Rocks of lower Miocene age are exposed in the apical region while toward the east and away from the core of the Range progressively younger sediments crop out in belts of varying widths. The Recruit Pass fault has downfaulted the western limb of this anticlinorium, bringing the older rocks of the core (Temblor-Vaqueros) into contact with the upper Miocene Santa Margarita formation (Fig. 8).

Nothing definite is known of the unexposed rocks below the uppermost part of the Eocene. It is believed, however, that there is a considerable thickness of Eocene and Cretaceous sediments overlying a "Franciscan" type of basement in this area, much as in the deeply eroded anticlinorium of the north part of the Temblor Range in the vicinity of Cedar Canyon. If this is the case, the sedimentary blanket above the basement in this area is in excess of 15,000 feet.

The stratigraphic section exposed in the central Temblor Range is shown graphically in Figure 2. The Miocene is thick and fairly complete, but Pliocene sediments so well developed in the Midway-Sunset oil district on the east, are not represented because of erosion and truncation by younger formations.

Correlation of the Miocene formations of the Recruit Pass area with the thick and well exposed sections of the Chico Martinez Creek area (location of the type Temblor formation and the type Zemorrian stage), on the northeast flank of the Range, has been possible through detailed studies of the foraminiferal assemblages from both localities. These studies have also permitted

age determinations of the various units in terms of the stage classification proposed by R. M. Kleinpell (4).

The locations of the important foraminiferal samples are plotted on the geologic map (Fig. 8). Only the samples which were determined as "Good" (G) or "Very Good" (V.G.) appear; samples which contained a meager or doubtful microfauna have been omitted for the sake of simplicity.

TEMBLOR-VAQUEROS FORMATION (LOWER MIOCENE-OLIGOCENE)

The Temblor-Vaqueros formation as used in this paper includes beds which can be correlated with the Media shale, the Carneros sandstone, the Santos shale, the "*Phacoides*" sandstone and the Salt Creek shale, all of which are members of the Temblor and Vaqueros formations in the classic Chico Martinez Creek section. Although these sandstone and shale members form distinct mappable lithologic units in the Chico Martinez Creek area they lose their individual identity as they are traced southward. In the Crocker Flat-Recruit Pass area this whole interval has greatly thickened into a predominant sand body containing intercalations of lenticular dark brown silts. Because of this lateral lithologic gradation, the section below the middle Miocene, in the south part of the Temblor Range, can not be divided into lithologic units comparable with the members of the Temblor and Vaqueros formations in the Chico Martinez Creek district. It has therefore been necessary to group the beds in the Recruit Pass area to include age equivalents of these two formations. There are, however, two lithologic facies of the Temblor-Vaqueros formation which can be recognized in the Recruit Pass area, namely, (1) the landslid Temblor-Vaqueros and (2) the *in situ* facies. The landslid facies was redeposited by gravity movement in upper Miocene time; consequently it is actually upper Miocene in age. However the writers have chosen to show in Figure 8, the areal distribution of the different formations involved in the Crocker Flat landslide rather than to group the landslide formations under the single caption of "Tls" (Tertiary landslide). In this manner they are better able to portray the mechanics of the landslide. The outline of the infolded post-Antelope-pre-Santa Margarita Crocker Flat landslide is shown by a prominent dot-and-dash symbol in Figure 8.

Landslid Temblor-Vaqueros.—The Temblor-Vaqueros remnants of the infolded Crocker Flat landslide are well exposed in the central part of the area shown in Figure 8. These beds consist of tan to chocolate brown siltstones and brownish gray sands which, although the structural details are not too clear because of landslide distortion, are believed to attain a maximum thickness of approximately 1,000 feet in the vicinity of Crocker Flat.

So-called Oligocene macrofossils have been collected from a 150-foot sandstone member lying within the landslid mass and traceable more than a mile through parts of Secs. 13 and 24, T. 31 S., R. 21 E., and Sec. 19, T. 31 S., R. 22 E. The following is a partial list of the fossils identified from this sandstone, compiled with the aid of W. F. Barbat of the Standard Oil Company of California.

**Turritella lorenzana* Wagner and Schilling
Epitonium condoni Dall
Strepsidura lincolnensis subsp. *lorenzana* Wagner and Schilling
"Pitar" clarki Dickerson
***Mulinia* aff. *eugenensis* Clark
Solen sp.

* In a recent communication Hubert G. Schenck states, regarding the *Turritella*, "It appears to me that the common species is probably *Turritella wheatlandensis*"
** Identified and added by Hubert G. Schenck.

Foraminiferal faunas collected above and below the sandstone containing these macrofossils were determined as Zemorrian (lower Miocene) in age, approximately equivalent to faunules found in the lower part of the Santos shale in the Chico Martinez Creek section.

Glenn C. Ferguson lists the following diagnostic Foraminifera from samples collected from the landslid Temblor-Vaqueros beds.

Siphogenerina transversa Cushman
Cibicides americanus (Cushman)
Bolivina marginata Cushman var. *"temblorensis"*
Nonion pompilioides (Fichtel and Moll)
Cibicides floridanus (Cushman)
Uvigerina hispida Schwager
Siphogenerina cf. *nodifera* Cushman and Kleinpell
Siphogenerina tenua Cushman and Kleinpell

The association of "Oligocene" macrofossils with Foraminifera of Zemorrian age is not exceptional. Lesh Forrest (5) concludes from his studies of the type San Lorenzo (Oligocene?) and adjacent formations in the Santa Cruz Mountains that,

> . . . no distinct faunal break between the San Lorenzo and Vaqueros formations could be detected by a study of numerous foraminiferal faunules . . . (and) . . . at least the upper 2500′ of the San Lorenzo and the lower 2000′ of the Vaqueros belong to the Zemorrian stage. . . .

Since the thickness of the San Lorenzo in the vicinity of the type locality is about 2,300 feet it is thought that only the lowest part could possibly carry foraminiferal faunules older than Zemorrian. H. G. Schenck (6) questioned the age of the Vaqueros formation of California and suggested the possibility that the whole formation might be Oligocene in age. His conclusions are in part based on the contention that there is no great faunal change between the Vaqueros and the immediate underlying formations. He states that (p. 525),

> The "great faunal break" at the close of the Oligocene is a myth both in Europe and America.

In regard to this problem R. M. Kleinpell (4, p. 153) states,

> Also associated with Zemorrian foraminiferal assemblages are the *Pecten sanctaecruzensis* "typical San Lorenzo" molluscan faunas of the Santa Cruz Mountains and—at least with those of lower Zemorrian age—the molluscan assemblages referable to the "San Ramon horizon," "Upper Pleito," "*Agasoma gravida* zone," or "*Acila gettysburgensis* zone," which, as with the *Acila schumardi* zone and the "*Turritella variata* zone," probably represent a deeper or cooler-water facies of the littoral tropical or subtropical fauna of the "*Turritella inezana*" zone.

For the purpose of this paper it seems more justifiable to use the term Vaqueros for strata containing both Zemorrian Foraminifera and so-called Oligocene macrofossils rather than introduce a non-indigenous Oligocene formational name such as "San Lorenzo" or "Pleito." Since certain samples within the Crocker Flat landslide also contain foraminiferal assemblages showing an affinity to the lower Saucesian (Media shale), it was advisable to group the strata of this age within the landslide, under a combined Temblor-Vaqueros caption.

In situ Temblor-Vaqueros formation.—The oldest rocks in place in this part of the Temblor Range comprise buff-gray sandstones with minor intercalations of brown siltstone and clay shale. These beds crop out along the crest of the Range. The maximum thickness exposed in the Recruit Pass area is approximately 1,800 feet. The base is not exposed but it is known from well sections that the total thickness is in excess of 3,000 feet.

Hudson and White (2) state that (p. 1329),

> There is no direct faunal evidence as to the age of these beds [the writers' Temblor-Vaqueros], but from paleontologic evidence from other parts of this region coupled with lithologic and structural considerations, they are, in conformity with Arnold and Johnson (1910, Pl. I), considered to be Vaqueros (lower Miocene).

No diagnostic macrofossils were found but the age of these beds can be accurately determined from a study of the abundant well preserved foraminiferal assemblages collected from the silts of the Temblor-Vaqueros. Ferguson reports,[5] on the basis of the many surface samples studied, that the outcropping Temblor-Vaqueros formation is Saucesian and upper Zemorrian in age and is approximately equivalent to the lower Media and Santos shales of the Chico Martinez Creek section. Some of the more important forms listed by him are:

Uvigerinella obesa var. *impolita* Cushman and Laiming
Cibicides americanus (Cushman)
Plectofrondicularia californica Cushman and Stewart
Siphogenerina transversa Cushman
Bolivina marginata Cushman var. *"temblorensis"*
Bulimina carnerosensis Cushman and Kleinpell
Cibicides floridanus (Cushman)
Siphogenerina lenua Cushman and Kleinpell

The *in situ* Temblor-Vaqueros is lithologically different from the landslid Temblor-Vaqueros in that it contains a much larger percentage of arenaceous beds. On the basis of foraminiferal assemblages the difference in age between the landslid and the outcropping Temblor-Vaqueros is apparently slight. In most cases the beds in place appear to be slightly younger than the landslid Temblor-Vaqueros. Both facies contain microfaunas characteristic of the normal stratigraphic section of the Temblor Range, and the stratigraphic position of each can be recognized in the well known Chico Martinez Creek section. It is believed that the age equivalent of the sandstone bed containing so-called Oligocene macrofossils, and found within the Crocker Flat landslide, belongs to

[5] Personal communication.

that part of the Temblor-Vaqueros which underlies the oldest beds exposed in the crest of the Range.

MONTEREY FORMATION (MIDDLE AND UPPER MIOCENE)

Devilwater-Gould member (*middle Miocene*)—The Monterey shale in the southern part of the Temblor Range can be subdivided into three lithologic and faunal units, the lowest of which is the Devilwater-Gould member. At the type area of the Temblor formation, in the vicinity of Chico Martinez Creek, the Devilwater silt, Gould shale and "Buttonbed" sandstone lens are distinct faunal and lithologic units characterized respectively by the *Valvulineria californica, Valvulineria robusta* and *"Scutella" merriami* faunal zones. In the Recruit Pass area an interval of 1,850 feet of well bedded, siliceous, light brown shale, with a minor amount of interbedded tan silt and lentils of massive buff limestone, comprise a single lithologic unit from which have been collected faunules common to both the Gould shale and the Devilwater silt as they are defined on Chico Martinez Creek.

The Devilwater-Gould member crops out in a northwest-southeast band trending diagonally across the geologic map (Fig. 4). Of special interest is the belt of landslid Devilwater-Gould, near the northeast margin of the Crocker Flat landslide in Secs. 11, 12, and 13, T. 31 S., R. 21 E., which rests on the younger McDonald shale. The landslid beds are lithologically and faunally identical with adjacent beds of Devilwater-Gould age which are definitely in place. The Devilwater-Gould member lies with apparent conformity on the Temblor-Vaqueros but is unconformably overlain (at least locally) by the McDonald shale.

Because of the absence of a lithologic break between the upper and lower parts of this mappable unit, the whole thickness is referred to as the Valvulineria zone; it is regarded as belonging to both the Relizian and Luisian stages of the middle Miocene. Diagnostic Foraminifera listed from this interval include the following:

Valvulineria robusta (Kleinpell)
Siphogenerina branneri (Bagg)
Anomalina salinasensis Kleinpell
Pullenia miocenica Kleinpell
Bolivina conica Cushman
Siphogenerina collomi Cushman
Valvulineria californica var. *obesa* Cushman
Pulvinulinella subperuviana Cushman

McDonald shale member (*upper Miocene*).—The McDonald shale can be differentiated lithologically from the underlying Devilwater-Gould member by its characteristic siltiness and massiveness. There is also a color change from the buff and tan of the Devilwater-Gould interval to the brownish gray and purplish gray of the McDonald shale. These beds crop out in a belt east of the Devilwater-Gould member, on the east side of the Temblor Range; they attain a thickness of 2,250± feet. Foraminifera found in this member belong to the well known

Pulvinulinella gyroidinaformis zone and are lower Mohnian in age. Characteristic Foraminifera include:

Pulvinulinella gyroidinaformis Cushman and Goudkoff
Uvigerina hootsi Rankin
Uvigerina modeloensis Cushman and Kleinpell
Bulimina uvigerinaformis Cushman and Kleinpell
Uvigerina carmeloensis Cushman and Kleinpell
Cassidulina monicana Cushman and Kleinpell

The McDonald shale rests unconformably on the Devilwater-Gould member, at least locally; it is overlain conformably by the Antelope shale.

Antelope shale member (upper Miocene).—The Antelope shale member includes a thickness of 2,400± feet consisting of siliceous, well bedded, light brown shale containing minor lenses of sandstone and limestone. It rests with conformity on the silty brownish gray McDonald shale member and it is overlain unconformably by the punky shales, sands, and conglomerates of the Santa Margarita formation.

The microfaunas of this unit are sparse but enough Foraminifera were found to correlate the lower part of the shale mapped as Antelope in the Recruit Pass area, with the *Bolivina marginata* var. *"multicostata"* zone of the Chico Martinez Creek area and to thus establish its upper Mohnian age. Exact correlations are impossible within the upper part of the Antelope shale because of the meager fauna. Barbat and Weymouth (7), on the basis of a zone of costate *Uvigerina* impressions, correlate a horizon approximately 500 feet below the top of the Antelope shale in the Crocker Springs area with a point about 450 feet below the top of the Antelope shale in Chico Martinez Creek. This correlation strongly suggests that the Antelope shale of the Crocker Flat area is equivalent to the Antelope shale as it is recognized on Chico Martinez Creek.

CROCKER FLAT LANDSLIDE (POST-ANTELOPE—PRE-SANTA MARGARITA)

The Temblor-Vaqueros and Devilwater-Gould strata which were involved in the Crocker Flat landslide have been discussed under previous headings.

SANTA MARGARITA FORMATION (UPPER MIOCENE)

The term Santa Margarita as used in this paper applies to (1) the punky diatomaceous shales and conglomerates above the Antelope shale and below the Etchegoin (Pliocene) formation, on the northeast side of the Range and (2) the extremely coarse clastics, conglomerates, sands, and shales containing upper Miocene macrofossils, in the summit area and on the southwest flank of the Range.

The writers resorted with reluctance to the application of the term Santa Margarita to the uppermost Miocene beds in this region because they are only in part similar lithologically to the type Santa Margarita. Also, it is believed that the upper part of the interval is younger than the type section. Local names could be introduced for these beds but it is felt that until a continuous and complete section is found, which contains adequate paleontologic control, the

coining of new names would only add confusion to an already complex problem.

The lithologic facies of the Santa Margarita are diverse, ranging from thinly laminated diatomaceous shales to clastics so coarse that they have been mapped as basement complex by some workers. It is believed that proximity to a land area of basement rocks, located either within or west of the San Andreas Fault zone, during Santa Margarita time, provided the source for the coarser facies of this formation. Depositional agencies with seasonal variations no doubt influenced the composition of the various lithologic facies laid down during this time. Alternating depositional conditions existed which resulted in the development of conglomerates and fluviatile channel deposits contemporaneously with littoral deposits in adjacent areas which were environmentally favorable for the existence and preservation of pectens, oysters, and echinoids.

On the northeast side of the Temblor Range the Santa Margarita consists of a series of grayish white diatomaceous punky shales with intercalated lenses of conglomerate and sand; a total thickness of approximately 2,700 feet is estimated for the area east of that shown in Figure 8.

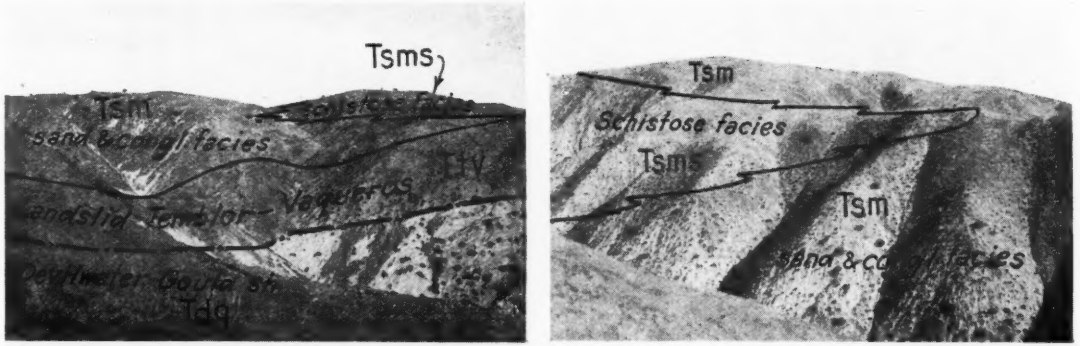
On the southwest flank of the Range shales are interbedded with the conglomerates and sands only in the area between Sec. 7, T. 32 S., R. 22 E., and Sec. 7, T. 31 S., R. 21 E. On the summit of the Range the Santa Margarita is composed largely of extremely coarse clastics, conglomerates, and sands. The sediments become finer north and south of Sec. 16, T. 31 S., R. 21 E., indicating that there must have been an easily accessible source, for coarse basement fragmental material, closely adjacent to this locality and probably within or west of the San Andreas fault.

In mapping the coarse detrital development of the Santa Margarita in Secs. 15 and 16, T. 31 S., R. 21 E., two distinct facies were recognized. One facies is made up almost entirely of schistose débris (Tsms) and the other presents a granitoid facies composed predominantly of granodiorite and quartz monzonite boulders (Tsmg). These rock types correspond rather closely in composition with the Sur Series and Santa Lucia "granite" as defined in the southern Coast Ranges by Trask (3).

The conglomerates and sands (Tsm) comprise the most common facies of the Santa Margarita on the southwest side of the Range. These beds are composed predominantly of granitoid boulders with minor amounts of schistose material and volcanic rock, set in a coarse gray sand matrix, locally containing good upper Miocene macrofossils.

Attention should be called to the vesicular basalt boulders found in the SE $\frac{1}{4}$ of Sec. 23, T. 31 S., R. 21 E. These boulders were deposited in Santa Margarita time and were probably derived from an area southwest of the San Andreas Fault zone.

A full section of Santa Margarita is nowhere exposed in this region because of faulting, but it is estimated that the maximum total thickness on the southwest side of the Range is about 4,000 feet.



A B

FIG. 3A and B.—Intertongueing of schistose facies of Santa Margarita with coarse conglomerate and sand facies along crest of Range in Sec. 15, T. 31 S., R. 21 E.

The Santa Margarita rests with marked unconformity on all older rocks and on the Crocker Flat landslide. Although this unconformity becomes less prominent basinward (toward the east), detailed subsurface studies have proved its existence. As is the case with many other unconformities in California, the unconformable relationships are more marked near the periphery than in the center of the basin. In the Recruit Pass area the Santa Margarita is overlain unconformably by the Tulare formation.

No Foraminifera were found in the Santa Margarita of this area but from studies of the macrofaunas it has been concluded that these beds are definitely upper Miocene in age. *Pecten estrellanus*, *Pecten crassicardo*, *Astrodapsis tumidus*, var., and *Ostrea titan* are some of the forms noted.

TULARE FORMATION (PLEISTOCENE)

Unconformably overlying the Santa Margarita in the Recruit Pass area is a series of non-marine, gritty, gray, buff sands and silts with minor lenses of pebbles and cobble conglomerate. These beds seems to become finer in texture toward the top. It is estimated that there is 1,000± feet of Tulare exposed in the vicinity of White's (Fig. 8).

The exact age of these beds is unknown but it is believed that they are at least partially equivalent to the Tulare on the northeast side of the Range because siliceous shale pebbles are common to both. It appears certain that much of the Temblor Range was high enough at the time of the deposition of these sediments to contribute Miocene siliceous shale fragments to these beds. The presence of Miocene siliceous shale fragments in these strata suggests that the deposits on the northeast and southwest sides of the Range are contemporaneous and both belong to the Tulare period of deposition.

Fragmental crystalline rocks, though present, are very much less prominent in the Tulare than in the Santa Margarita beds, indicating that the source areas of this material were of less importance during Tulare time. There is a possibility that the crystalline rock pebbles and cobbles found in the Tulare were derived entirely from exposed Santa Margarita clastics.

ALLUVIUM (HOLOCENE)

Recent alluvium rests with angular discordance on the Tulare and covers the valley between the Panorama Hills and the Temblor Range in the western part of the area mapped.

STRUCTURE

GENERAL

The Temblor Range trends southeast for more than 50 miles from its general northwestern terminus near Polonio Pass, where it joins the Diablo Range, to the point where it merges with the San Emigdio Range on the southeast. The Range is bounded on the southwest by the famous San Andreas Fault zone. Its general structure, in the northern half, is that of a southeastward-plunging anti-

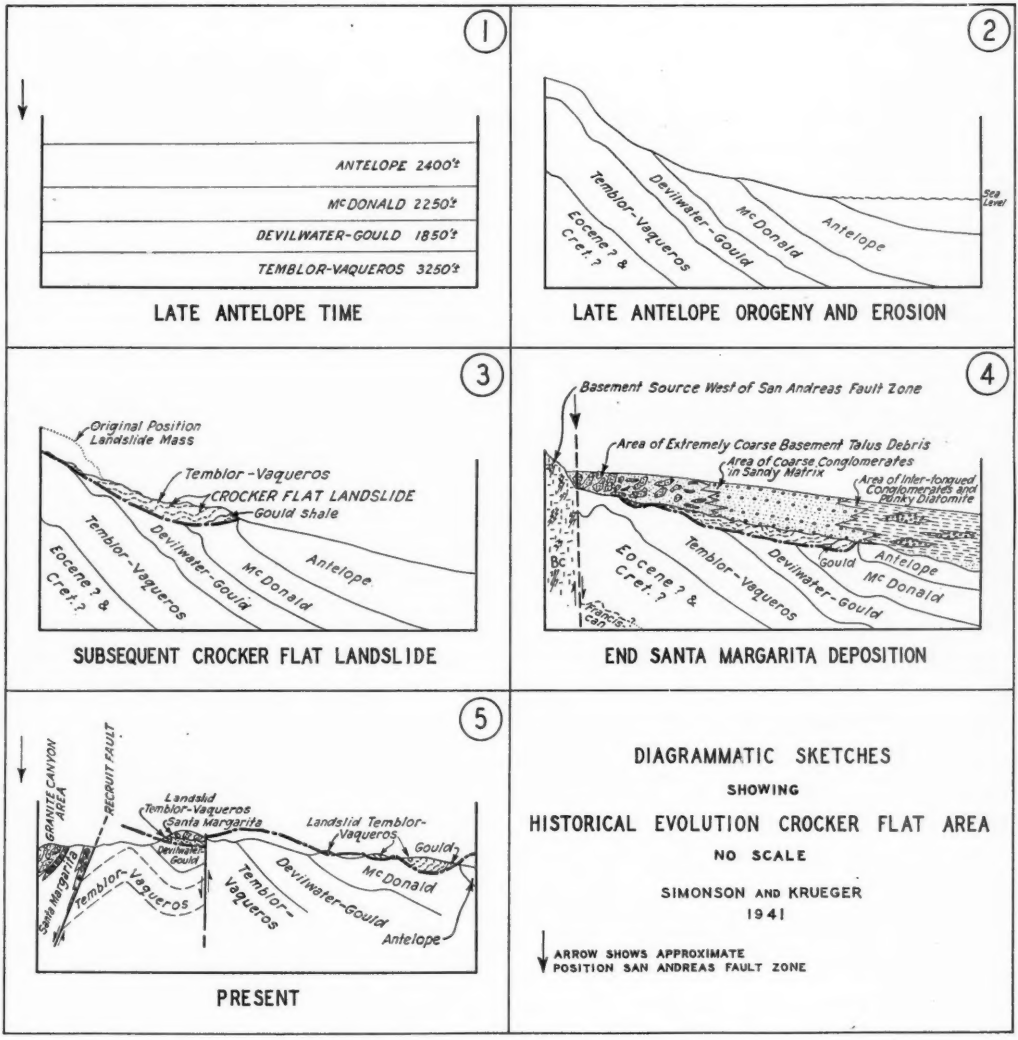


FIG. 4.—Diagrammatic sketches showing historical evolution, Crocker Flat area.

clinorium; Franciscan (Jurassic?) basement rocks and Cretaceous strata comprise its core in the northern part.

In the south half of the Range, south of Salt Creek, the structure is that of a faulted anticlinorium with increasingly intense faulting and high-angle folding as the San Andreas Fault zone is approached. In this south half, the oldest rocks exposed are of lower Miocene-upper Oligocene age, in contrast to the Franciscan and Cretaceous core farther to the north.

Crocker Flat-Recruit Grade area.—In attempting to unravel the complexity of folding, faulting, and landsliding in this area the writers have relied on the detailed tracing of certain well defined lithologic units from north to south and the repeated checking of the microfaunas of these units in order to eliminate the possibility of stratigraphic errors due to lateral lithologic changes. In all cases every effort has been made to subdivide the stratigraphic section in terms of the type succession of rocks exposed in the Chico Martinez Creek drainage.

Figure 8 portrays the intricate structure of the Crocker Flat-Recruit Pass area and depicts the outline of the infolded Crocker Flat landslide. The locations of more than 50 surface samples are shown, all of which contained foraminiferal assemblages which Glenn Ferguson considers diagnostic. The reliability of these samples has been graded into two classes, "G" (Good) and "VG" (Very Good). Approximately 100 other samples were collected in this area which were barren or yielded relatively poor microfaunal assemblages; these localities are not shown in Figure 8. The so-called Oligocene macrofossils were collected from the sandstone bed shown in Figure 8 by a line of circled capital F's; this fossiliferous sandstone was traced for a horizontal distance of more than a mile.

Figure 8 shows only a selected few of the many hundreds of dips and strikes taken. We do not mean to imply that all of the inclinations taken agree so perfectly with the structure as represented. Squeezed, pinched, and drag folding, along with minor faulting, give the detailed map a much more complicated appearance.

Four facies of the Santa Margarita are shown in Figure 8, namely, the coarse granitoid facies of Granite Canyon,[6] the schistose facies of this same locality and areas in Section 15 on top of the Range, the sand and conglomerate facies common to both flanks of the Range, and the punky diatomaceous shale facies of the northeast side of the Range. It is unfortunate that none of the coarse clastic lenses, which are so characteristic of the punky facies on the northeast side of the Range, falls within the limits of this map. A number of lenses prominently crop out a short distance east of the eastern boundary of Figure 8.

The writers have been particularly careful to separate the different lithologic facies of the Santa Margarita in Figure 8. They have also shown, in some instances, the manner in which one facies is intertongued with another. The enormous granitoid blocks of Granite Canyon have been shown as the granitic facies

[6] The writers have taken the liberty of naming the locality of the coarsest detrital granitic material, in Sec. 16, T. 31 S., R. 21 E., Granite Canyon.

of the Santa Margarita; they are thought to be a landslide remnant. A prominent lens of the coarse schistose facies, which tongues out northwest and southeast, is also shown in Granite Canyon at a somewhat lower stratigraphic position than that represented by the huge granodiorite blocks. On the top of the Range, in Section 15, the coarsest detrital facies is predominantly schistose material, and it is shown intertongueing, both northwest and southeast, with the conglomerate and sand facies.

Crocker Flat landslide.—Topographically, Crocker Flat is an area of low relief which interrupts the normal higher elevation of the Temblor Range; within it a

FIG. 5.—Eastern margin of Crocker Flat landslide at point where Recruit Pass road crosses. Looking north.

billowy type of topography, characteristic of landslides everywhere, is well developed. The Crocker Flat landslide is composed almost entirely of sediments belonging to the Temblor-Vaqueros formation. There is, however, one important exception. Along the northeast border of the main Crocker Flat landslide a thin strip of Devilwater-Gould shale is shown within the landslid mass; this strip can be traced more than a mile. The best place to observe the base of this landslide is at the south end of the lobe where the contact flattens to about 20° in inclination. The contact on the eastern margin of the landslide is inclined southwest 50°–90° and it can be observed at the point where the Recruit Pass road crosses the contact in Section 13. Exposures along this contact are much better farther southeast and a cursory examination near the road would not necessarily convince the observer that he had seen the base of an infolded "fossil landslide."

On top of the Range, in Section 15, the landslid Temblor-Vaqueros has a maximum thickness of 100 feet and it is in this area that Hudson and White (2) identified it as a gouge zone in their Recruit Pass fault. In a fault of this magnitude such a gouge zone would be expected to contain fragments from the overriding crystalline basement mass. Trenching showed the entire interval to be

composed of shales and silty sands, containing a Temblor-Vaqueros microfauna and uncontaminated by fragments of the overlying crystalline rocks. Thus the evidence does not support Hudson and White's identification of this interval as a gouge zone.

The relationship between the Santa Margarita and the Crocker Flat landslide is particularly well shown near the east quarter corner of Sec. 24, T. 31 S., R. 21 E., where a small remnant of Santa Margarita conglomerate and sand rests unconformably on the landslid Temblor-Vaqueros. This small remnant has, since its deposition, been folded into a small syncline and faulted along its northeastern margin.

FIG. 6.—Landslid Temblor-Vaqueros formation resting on Devilwater-Gould and unconformably overlain by Santa Margarita schistose facies.

Recruit Pass fault.—This northwest-southeast trending normal fault has brought Temblor-Vaqueros sands and shales on its northeastern or upthrown side into contact with Santa Margarita conglomerates and coarse clastics on its southwest side. Careful mapping of this fault contact shows its plane to be inclined southwest. No good exposure of the fault plane was found, but topographic evidence suggests that its dip approximates 60°.

Cross sections.—Cross section *AA'* shows, from west to east, the coarse detrital Santa Margarita in Granite Canyon, the intertongued schistose facies west of the Recruit Pass fault, the coarse clastic schistose facies on top of the Range in Section 15, and the landslid relationships of this last locality and farther east. This section passes through the north part of the Crocker Flat area near the locality where the Recruit Pass road crosses the eastern margin of the landslide.

Section *BB'* was drawn primarily to show the relationships within the main area of the Crocker Flat landslide. The location of the so-called Oligocene macrofossils is shown, as well as the unconformable superposition of the Santa Margarita upon the landslid mass.

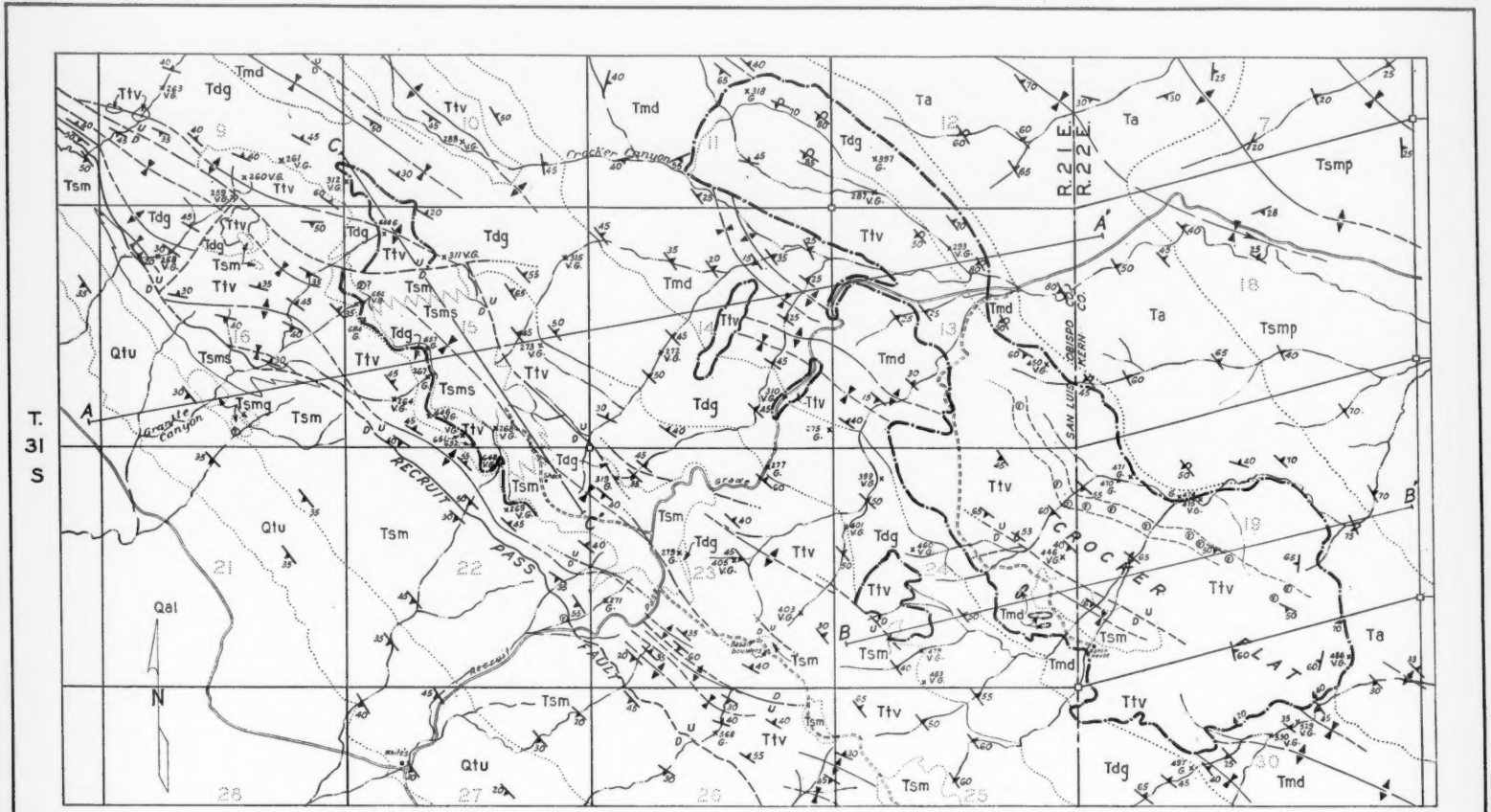
Section *CC'* portrays the manner in which the very coarse detrital schistose facies of the Santa Margarita, on top of the Range in Section 15, fingers out northwest and southeast and grades into the conglomerate and sand facies.

FIG. 7.—Trench through landslid Temblor-Vaqueros shale and silty sands. Interval is uncontaminated by fragments of crystalline rocks. Landslid Temblor-Vaqueros is resting on Devilwater-Gould shale.

HISTORICAL EVOLUTION OF CROCKER FLAT AREA

Figure 4 portrays the chronological development of the infolded Crocker Flat landslide. It shows five time periods beginning at the end of Antelope shale deposition and including the present. These diagrammatic sketches are of necessity considerably simplified for the sake of clarity in presentation. It has been necessary to exaggerate some of the depositional and structural features, both as to scale and as to the degree of folding and faulting, in order to make the drawings more understandable.

1. *Late Antelope time.*—It is thought that deposition beginning with Temblor-Vaqueros time and continuing to late Antelope time was fairly constant. However, depositional agencies and the positive areas contributing the sediment were constantly changing as evidenced by the varieties of lithologic facies deposited. Elsewhere in the Range there is evidence of an unconformity at the base of the McDonald shale but as this has no bearing on the present problem it is not discussed here. A total thickness of approximately 10,000 feet of Miocene sediments was laid down with only minor tectonic interruption.


T. 31 S
R. 21 E.
R. 22 E.
SAN LUIS OBISPO CO.
KERN CO.
Cracker Canyon
Granite Canyon
RECRUIT PASS
FAULT
CROCKER FAULT
Recruit
A
A'
B
B'
C
C'
N
Qal
Qtu
Tsm
Tsms
Tsmg
Tsmp
Ttv
Tdg
Tmd
Ta

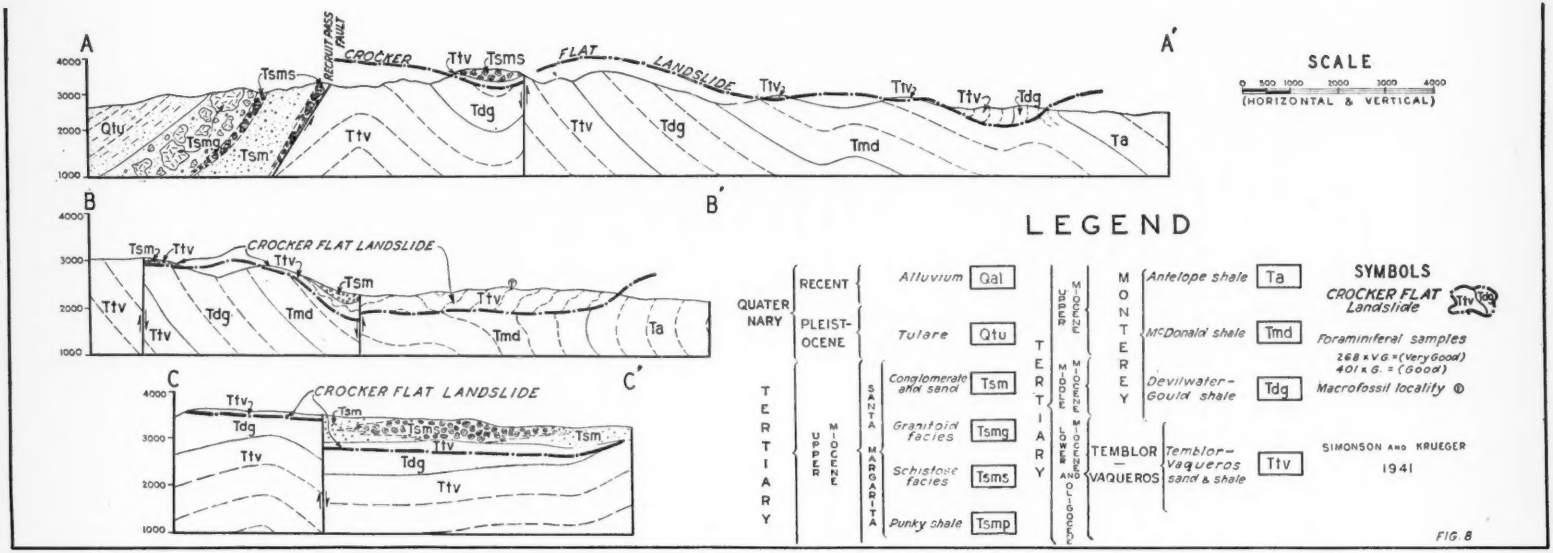


FIG. 8.—Geological map of Crocker Flat Landslide area, with three cross sections.

2. *Late Antelope orogeny and erosion.*—During late Antelope time, the Range was uplifted and slightly folded. This orogeny may have been no more than a severe eastward tilting, accompanied by minor folding, as shown in the second sketch. There is, however, some evidence suggesting that pinched folding and associated faulting accompanied this period of compressional activity. This orogeny resulted in elevation of the Temblor Range and the following period of erosion undoubtedly developed prominent topographic relief through the central part of the Range. There is some suggestion that locally, uppermost Antelope shale may have been deposited contemporaneously with the orogeny and erosion, especially in the seaward area closely adjacent to the Range on the northeast. This is evidenced by the presence of a reworked (?) "bastard" microfauna in the middle part of the Antelope consisting of a heterogeneous assemblage of older forms than those ordinarily found. This has been taken as evidence indicating that there was a weak diastrophic impulse, a forerunner of the strong late Antelope orogeny, prior to the end of Antelope time.

3. *Crocker Flat landslide.*—Following the development of prominent topographic relief in the Temblor Range region, and before the beginning of Santa Margarita time, the writers believe that a topographically high mass, composed of sediments belonging to the upturned edges of the Temblor-Vaqueros and the Devilwater-Gould intervals, broke loose from the high crestal region of the Temblor Range and slid down its east slope. It came to repose in a jumbled mass upon the upturned edges of the Temblor-Vaqueros formation, Devilwater-Gould shale, McDonald shale, and Antelope shale. This mass piled up at the base of the landslide, its easternmost limit extending across the McDonald shale-Antelope shale contact in at least one locality. It appears that the distance between the westernmost breakage point of the landslide on top of the Range, and the easternmost point where the slide came to rest, was approximately 4 miles.

From a study of the microfaunal assemblages found within the landslid mass, and those from the adjacent *in situ* surface outcrops of the Temblor-Vaqueros, Ferguson[7] states that certain of the microfaunas from within the landslid mass are from a stratigraphic position somewhat lower than the faunas from the Temblor-Vaqueros in place. This would make it necessary for the slide to originate from a point farther west than the present outcropping Temblor-Vaqueros in this region, in order that it might include in the slide material, the lower part of the Temblor-Vaqueros. In terms of the Chico Martinez Creek section the majority of the faunas found within the Crocker Flat landslid mass would come from the Santos shale equivalent while the samples from the Temblor-Vaqueros, exposed on the surface in this locality, would be correlated with the lower Media and upper Santos shale part of the Chico Martinez Creek section. Thus the so-called Oligocene macrofossil assemblage found within the Crocker Flat landslid mass is associated with Zemorrian Foraminifera.

4. *End of Santa Margarita deposition.*—The fourth sketch in Figure 4 is shown

[7] Personal communication.

primarily to portray the four different lithologic facies developed contemporaneously within the Santa Margarita and to indicate an adequate and adjacent basement rock source for the coarse crystalline clastics which make up by far the greater part of the volume of these sediments.

At the close of Antelope time the Temblor Range must have entered a short period of subsidence. Late Antelope tilting was in an easterly direction. The pre-Santa Margarita subsidence may have had a tendency to lessen the attitude of the late Antelope tilt. Contemporaneous faulting along the San Andreas Rift line could have moved basement rocks on the west side of the fault into a favorable position to furnish the abundant coarse detritus of the Santa Margarita formation.

North of the south end of the Carrizo Plains, basement rocks on the southwest side of the San Andreas Fault zone consist of a combination of granodiorites and inclusions of mica schists, quartzites, marbles, gneisses, and crystalline limestones (Santa Lucia and Sur series). It is evident, from a study of the rock content of the Santa Margarita coarse clastics, that this type of basement furnished the major part of the material for this formation. In places the Santa Margarita consists almost entirely of a heterogeneous assemblage of mica schists, quartzites, and marbles (schistose facies). Elsewhere prominent "granitoid facies" of Santa Margarita conglomerate are noted in which schistose rock types are almost excluded. These variable concentrations are thought to be accountable to the proximity of these areas to basement rocks in which one rock type predominates over the other.

As has been stated under Stratigraphy, the writers have divided the Santa Margarita into four lithologic facies. These are as follows.

A. and B.—Close to shore granitoid (A) and schistose (B) extremely coarse clastics including talus débris, outwash fans, and in some instances landslid masses. These coarse clastics were all deposited adjacent to their source. Little or no bedding is developed and fragmental masses of enormous size are noted. The exposures in and near Granite Canyon and on top of the Range in Sec. 15, T. 31 S., R. 21 E., are characteristic of these facies. It is thought that the prominent exposures of granitic material in Granite Canyon represent either landslid masses or remnants of talus deposits contiguous to the basement source.

C.—Coarse conglomerate and sand facies. These deposits represent an intermediate stage between the extremely coarse clastics on the west and southwest and the interbedded conglomerates and diatomite on the northeast. Cross-bedding is prominent, sorting is poor, and rapid gradation from coarse conglomerates to coarse sands and on to fine sand is evident. There is, of course, no sharp boundary line between the extremely coarse clastic phase and the coarse conglomerate and sand facies; the cessation of steep gravity gradients and the slackening of torrential streams, upon crossing the northeast boundary of the San Andreas Fault zone, would explain this facies change. The coarse conglomerate and sand facies is characteristic along the crest of the Range and along its southwest side, south from Sec. 7, T. 31 S., R. 21 E. to Sec. 7, T. 32 S., R. 22E.

D.—Intertongued conglomerate and diatomite. This facies is characteristically developed along the northeast side of the Range between McKittrick and Maricopa. The huge lenses of conglomerate were deposited by torrential streams heading in a high land on the west. These streams debouched their load of coarse material into shallow seas in which thick deposits of diatomaceous sediments were accumulating.

This conglomerate and diatomite facies is strikingly different from the coarse conglomerate and sand facies developed in the intermediate area but this abrupt change is only apparent because recent erosion has stripped away the Santa Margarita which was deposited in the intervening area between the present crest and the northeast front of the Range.

W. F. Barbat, in an oral communication, states that this conglomeratic material can be recog-

nized no farther northeast than the present Midway Valley. It is of interest to consider that these four facies were all developed within a horizontal distance of between 10 and 12 miles.

The "fossil Crocker Flat landslide" was rapidly buried beneath facies *B* and *C* of the Santa Margarita; this is indicated by the erosional remnants which are now unconformably superimposed upon it.

5. *Present.*—Subsequent orogeny added to the structural complexity of the Temblor Range area and infolded the buried Crocker Flat landslide. Recent erosion, which has no doubt removed the major part of this old landslide, has left a number of erosional outliers and infolded remnants of it.

SUMMARY OF CONCLUSIONS

1. The crystalline rocks which occur in the region north of Recruit Pass Road, which were formerly mapped as pre-Cretaceous basement complex, are actually coarse detrital constituents of the Santa Margarita formation. This is attested by their intertongueing with coarse sands which contain upper Miocene (Santa Margarita) macrofossils in adjacent areas.

2. These fragmental crystalline rocks of Santa Margarita age are not foreign to the normal sedimentary section of the Temblor Range. Consequently, this eliminates the necessity of accounting for their presence by low-angle thrust faulting or horst faulting of cryptovolcanic origin.

3. Erosional outliers of Santa Margarita rest unconformably on older rocks and on the Crocker Flat landslide along the crest of the Temblor Range and are not *klippen* from a low-angle thrust plate. These beds were deposited unconformably upon strata ranging in age from Temblor-Vaqueros to McDonald. They also were deposited unconformably upon landslid Temblor-Vaqueros in the Crocker Flat area.

4. The Temblor-Vaqueros sediments which overlie younger Miocene beds in the vicinity of Crocker Flat are infolded remnants of the post-Antelope—pre-Santa Margarita Crocker Flat landslide. The microfauna of these landslid sediments prove that they are indigenous to the normal section of the Temblor Range and not necessarily foreign sedimentaries of older age thrust in from an area west of the San Andreas Fault zone.

5. The so-called Oligocene (San Lorenzo) macrofossils of the Crocker Flat area are associated, both above and below, with microfaunal assemblages belonging to the Santos shale (Saucesian and Zemorrian stages) as it is represented in the uninterrupted Chico Martinez Creek exposures.

6. Physical evidence favors a landslide contact between the Temblor-Vaqueros formation and the Devilwater-Gould shale in the SW. $\frac{1}{4}$ of Sec. 15, T. 31 S., R. 21 E.

7. The Recruit Pass fault is a normal fault marking the approximate northeast boundary of the San Andreas Fault zone. The east side of this fault is upthrown and movement along this line of weakness probably caused much of the present day elevation of the Temblor Range.

REFERENCES

1. ARNOLD, R., AND JOHNSON, H. R., "McKittrick-Sunset Oil Region," *U. S. Geol. Survey Bull. 406* (1910).
2. HUDSON, F. S., AND WHITE, G. H., "Thrust Faulting and Coarse Clastics in the Temblor Range, California," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, No. 7 (July, 1941), pp. 1327–42.
3. TRASK, P. D., "Geology of Point Sur Quadrangle, California," *Univ. California Pub.*, Vol. 16, No. 6 (1926), pp. 119–86.
4. KLEINPELL, R. M., *Miocene Stratigraphy of California* (Amer. Assoc. Petrol. Geol., 1938).
5. FORREST, LESH, "Type San Lorenzo Formation, Santa Cruz County, California" (abstract), *Geol. Soc. America Cordilleran Section* (Berkeley meeting, April 9, 1937), p. 5.
6. SCHENCK, H. G., "What Is the Vaqueros Formation of California and Is It Oligocene?" *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 4 (April, 1935), pp. 521–36.
7. BARBAT, W. F., AND WEYMOUTH, A. ALLEN, "Stratigraphy of the *Borophagus littoralis* Locality, California," *Univ. California Pub.*, Vol. 21, No. 3 (1931), pp. 25–36.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 26, NO. 10 (OCTOBER, 1942), PP. 1632-1646, 8 FIGS.

PAYTON POOL, PECOS AND WARD COUNTIES, TEXAS[1]

RICHARD E. GILE[2]
Midland, Texas

ABSTRACT

The Payton pool is one of a number of pools which produce oil and gas from sandstone on the west side of the Central Basin platform of the West Texas Permian basin. The pool was discovered in 1937 by a well located to test a probable subsurface structure in the zone of favorable sand development in the Yates sand. Oil and gas are produced from discontinuous sand beds in 240 feet of Yates sand section. An anticline controls presence of gas or oil, but lateral gradation eastward from sand into sandy shale and anhydritic sand controls production. The pool covers 1,325 acres on which 134 producing wells have been drilled. Cumulative production to September 1, 1940, was 1,700,000 barrels, or 1,280 barrels per acre.

INTRODUCTION

The Payton pool is herein described as of September, 1940.

Location.—The Payton pool is in the belt of pools which produce oil and gas from sandstone on the west side of the Central Basin platform, and is located on the north and south banks of the Pecos River in southern Ward and northern Pecos counties, Texas, about 4 miles southwest of the town of Grand Falls (Fig. 1).

DISCOVERY

The Payton pool was discovered by J. J. Dorr *et al.* in November, 1937, on subsurface structure determined by E. Russell Lloyd, through completion of Dorr Payton No. 1, Sec. 99, Block 8, H&GN Survey, Pecos County, flowing initially 39 barrels per day, from the upper part of the Yates sand at the total depth of 2,037 feet. The second well, Hoss and Downey's Cordz No. 1, one mile northeast in Section 81, was completed, December, 1937, with an initial natural flow of 87 barrels per day, from the upper part of the Yates sand at the total depth of 2,034 feet. The third well, the Cities Service Oil Company's Brandenburg No. 1, was completed as a gas well producing from the lower part of the Yates sand at 2,150 feet. This well is in Sec. 4, Block 32, H&TC Survey, Ward County, 2 miles east of the oil discovery.

At the close of 1938, a total of 59 producing wells had been drilled in the pool, and six dry holes had been completed to define the limits of production from the Yates sand pay zones on the northwest, west, and east. In September, 1940, when this article was written, 134 producing wells had been completed in the Yates sand. The productive area of the pool includes 1,325 acres.

Maximum development in the Payton pool occurred from December, 1938, to June, 1939, during which period 57 oil wells were completed, or more than 42 per cent of the total wells in the pool. Maximum production in the pool was in July, 1939, when the pool produced 120,000 barrels from 116 wells, or an average production of 33.4 barrels per well per day.

[1] Manuscript received, May 15, 1942.

[2] Consulting geologist, Thomas Building.

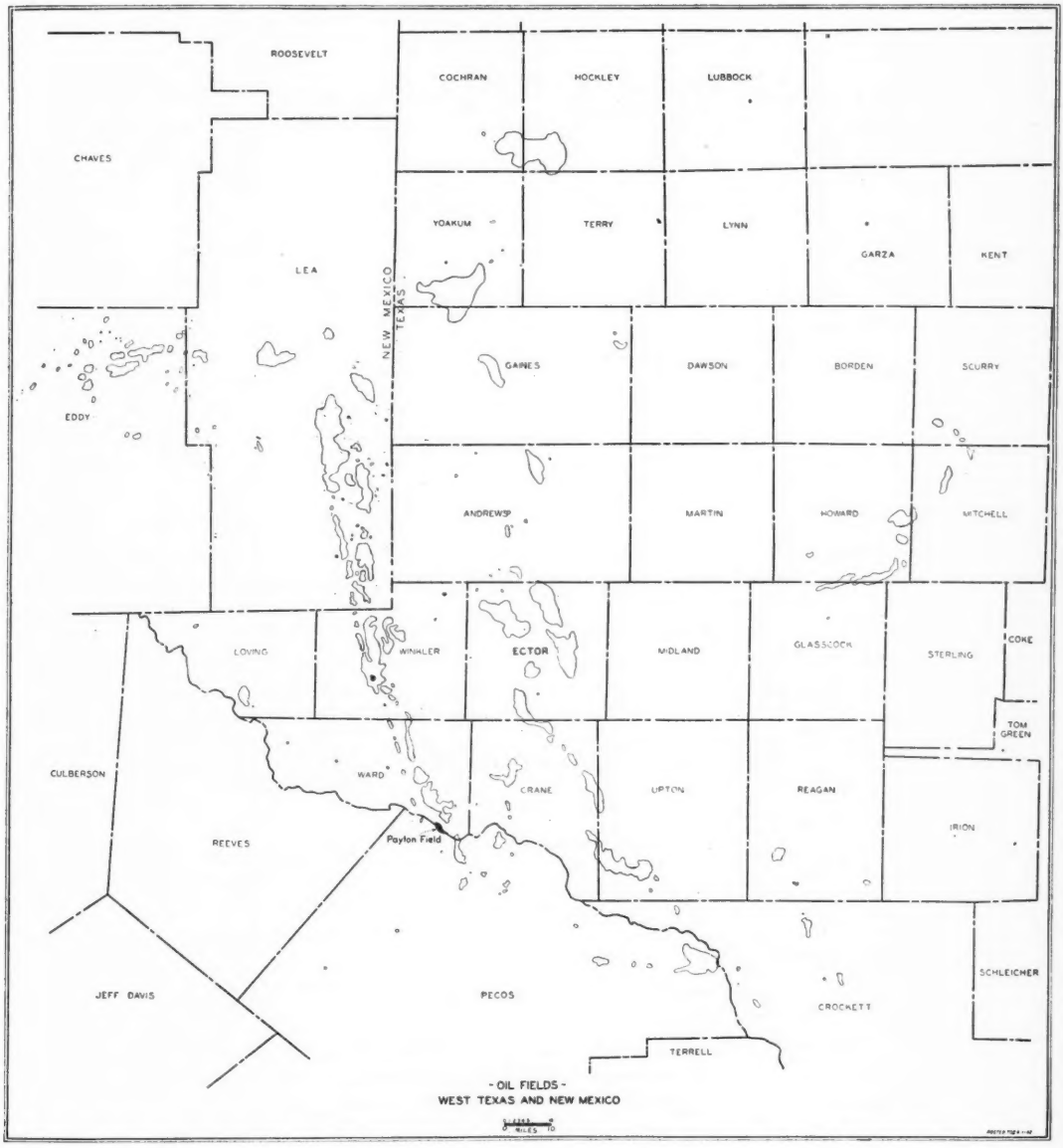


FIG. 1.—Map of West Texas and southeastern New Mexico showing location of Payton pool with relation to other producing areas.

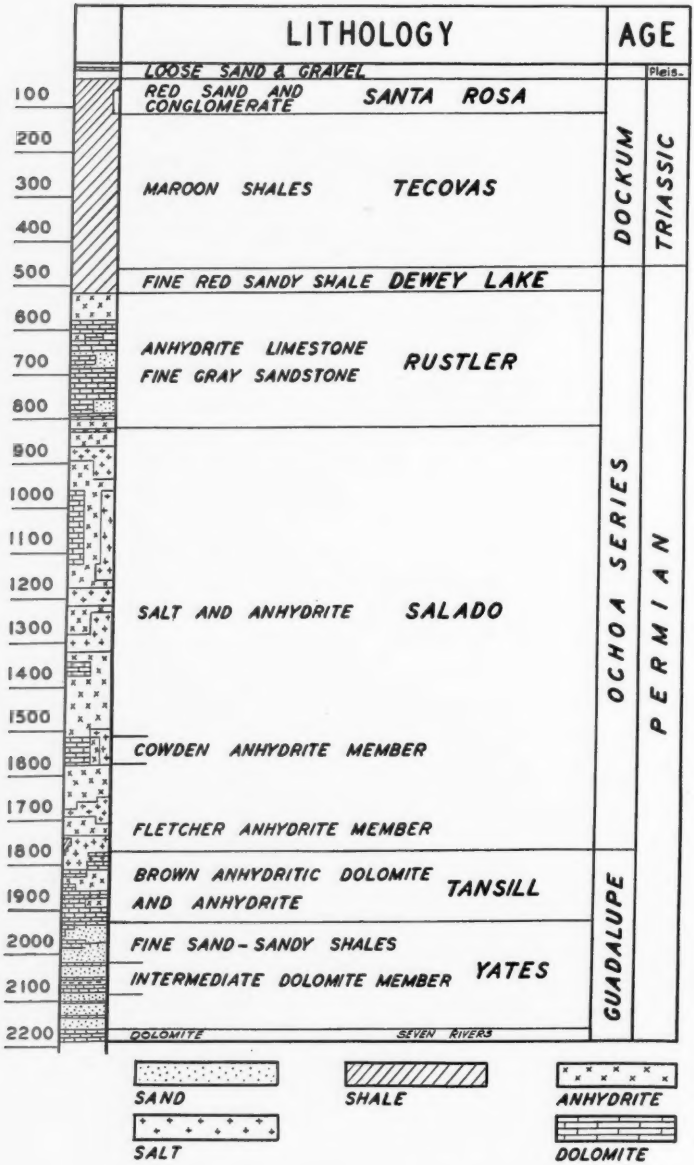


FIG. 2.—Stratigraphic column, Payton pool.

The Payton pool is served by the Atlantic Pipe Line Company which operates a 4-inch line from the area.

STRATIGRAPHY

Surface formations over most of the Payton pool are Pleistocene and Recent fill from the flood waters of the Pecos River which bisects the pool northwest and southeast. During low-water stages, a reddish conglomeratic sandstone can be seen in the bed of the river. This conglomerate is believed to be Triassic and may be correlated with the Santa Rosa sandstone (Fig. 2).

Subsurface formations include the typical sequence found in other pools producing from sand beds on the west flank of the Central Basin platform, with the exception that wells in the Payton pool encounter Santa Rosa beds immediately below the surface, as the Cretaceous basement sands and the Triassic Chinle formation are absent in this area because of its regionally high position on the south part of the Central Basin platform. Most wells in the Payton pool are completed in the Yates sand, and only two wells have penetrated into the Seven Rivers formation which underlies the Yates.

TRIASSIC

The Santa Rosa and Tecovas are the only members of the Triassic found in the Payton pool.

Santa Rosa sandstone.—Immediately below the surface formations, the Santa Rosa sandstone is represented by about 60 feet of coarse reddish sandstone. This thickness is comparable with 250–450 feet of Santa Rosa beds elsewhere in the West Texas section and indicates truncation of the upper part of the formation.

Tecovas formation.—Below the Santa Rosa sandstone, a series of red and maroon shales about 350 feet thick is penetrated. These shales are assigned to the Tecovas because of their position immediately below the Santa Rosa and above the Dewey Lake formation.

PERMIAN OCHOA SERIES

All additional beds penetrated by the drill in the Payton pool are included in the Ochoa and Guadalupe series.

Dewey Lake formation.—Below the Tecovas formation, wells in the Payton pool penetrate about 60 feet of very fine-grained red sandy shales. The red color of the Dewey Lake beds is brighter than that of the overlying Tecovas, and fine sands occur in the Dewey Lake but are absent in the Tecovas in this area.

Rustler formation.—The Rustler formation is penetrated below the Dewey Lake and comprises about 300 feet of buff, medium to coarsely crystalline, and locally oölitic porous dolomitic limestone, with some white to buff, coarsely crystalline anhydrite beds at the top and bottom of the formation. The Rustler is somewhat thicker in the Payton pool than in wells on the east, and contains much more dolomitic limestone. Many wells encounter a sand bed 20–30 feet thick about 150 feet below the top of the Rustler. Generally, a fine red and gray

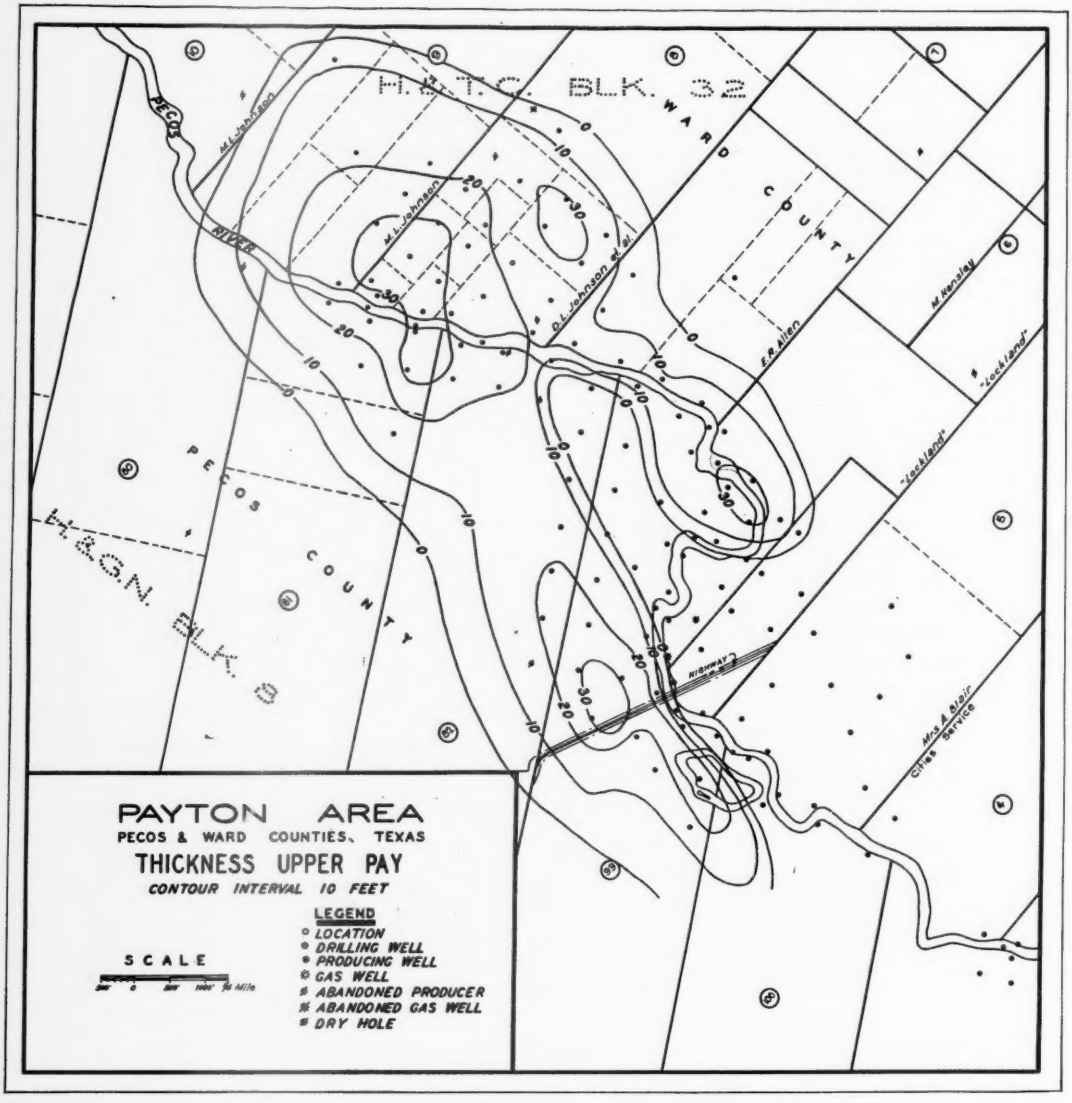


FIG. 3.—Isopach map of Payton pool showing thickness of oil-saturated sand, upper pay zone.

sandy shale bed occurs near the base of the formation. Two zones containing sulphur water occur in the Rustler formation in this area: the upper zone, about 15 feet thick, occurs in porous dolomitic limestone 70–85 feet below the top of the formation; the second water zone, also in porous dolomitic limestone, is found about 160 feet below the top of the Rustler.

Salado formation.—Below the Rustler, the drill penetrates 850–1,150 feet of salt and anhydrite beds which are assigned to the Salado formation. The Cowden anhydrite member, defined by Giesey and Fulk,[3] occurs about 240 feet above the base of the Salado in this pool. The greatest variation in thickness of formations encountered in the Payton pool occurs in the Salado formation. It is thinnest over the axis of the structure, 850 feet, and thickens east of the productive limits of the pool to about 1,150 feet. The Fletcher anhydrite member, defined by Lang,[4] is represented by 50–90 feet of massive dense anhydrite below the salt section of the Salado, and above the underlying Tansill formation.

PERMIAN GUADALUPE SERIES

WHITEHORSE GROUP

Beds of the Whitehorse group penetrated in wells of the Payton pool are the Tansill formation, the Yates sand, and the upper part of the Seven Rivers formation. (The Seven Rivers formation was penetrated in only two wells in the pool, as the Seven Rivers lies below the Yates sand which includes the producing zones of the pool.)

Tansill formation.—Below the Salado occurs the Tansill formation, which in the Payton pool consists of about 150 feet of gray and white, fine to medium, crystalline anhydrite and brown anhydritic dolomite at the base.

Yates sand.—The Yates sand contains the producing zones in the Payton pool and consists of about 240 feet of interbedded fine sandstones, loose sand, red and green sandy shale, and red and green shale, with a consistent intermediate dolomite section about 60 feet thick, occurring approximately 90 feet below the top of the formation. This dolomite separates the upper pay section from the lower pay section.

The upper pay section comprises the upper 90 feet of the Yates sand in this area and consists of several apparently discontinuous beds of fine gray sandstone, gray and green sandy shale, and gray and green shale. These beds are not correlative, bed for bed, even in adjacent wells, and the individual beds are lenticular. There is a consistent bed of dolomite 3 or 4 feet thick about 35 feet below the top of the Yates sand in nearly every well in the pool. This dolomite is relatively impermeable, and serves to divide the upper pay section into upper and lower members. Both the upper and the lower members of the upper Yates section

[3] Sam C. Giesey and Frank Fulk, North Cowden Field, Ector County, Texas, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, No. 4 (April, 1941), p. 603.

[4] Walter B. Lang, "Basal Beds of Salado Formation in Fletcher Potash Core Test near Carlsbad, New Mexico," *ibid.*, Vol. 26, No. 1 (January, 1941), p. 75.

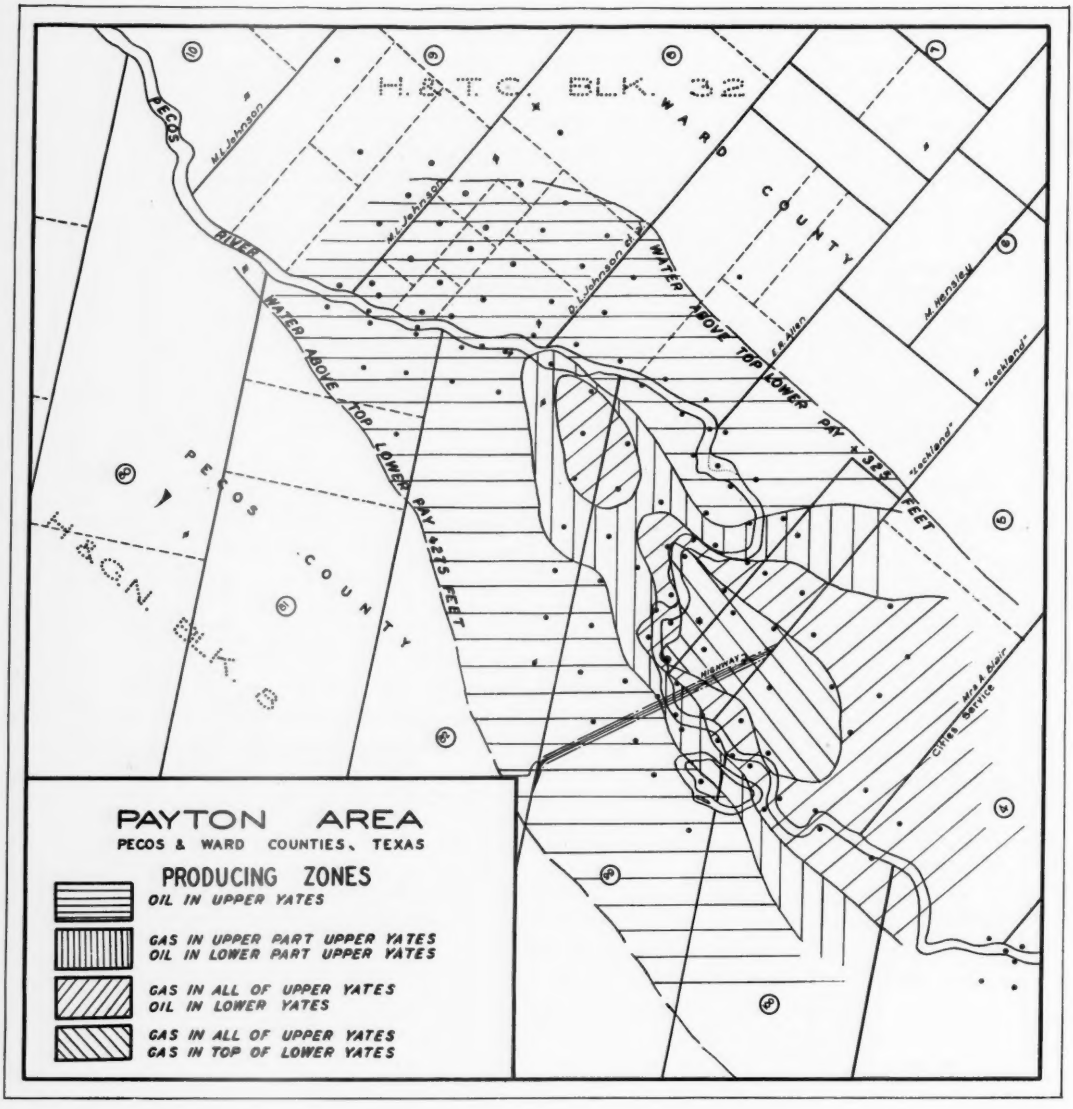

H. & T. C. BLK. 32
WARD COUNTY
PECOS RIVER
WATER ABOVE TOP LOWER PAY 1425 FEET
WATER ABOVE TOP LOWER PAY + 325 FEET
PECOS COUNTY
H & G.N. BLK. 8
M. Henslee
"Iceland"
Texas Highway
Mrs. A. Blair
Cities Service
PAYTON AREA
PECOS & WARD COUNTIES, TEXAS
PRODUCING ZONES
OIL IN UPPER YATES
GAS IN UPPER PART UPPER YATES
OIL IN LOWER PART UPPER YATES
GAS IN ALL OF UPPER YATES
OIL IN LOWER YATES
GAS IN ALL OF UPPER YATES
GAS IN TOP OF LOWER YATES

FIG. 4.—Map of Payton pool showing areas of producing zones.

contain oil on the flanks of the structure. High on the structure, the uppermost zone contains only gas, and at the crest of the structure even the lower member of the upper Yates section contains considerable gas. The actual thickness of oil-saturated sand in the upper Yates section varies from 0 to 35 feet (Fig. 3). The pay thickness maps as drawn show only oil saturated sand and do not include sand saturated with gas; thus, they do not represent total thickness of the sand members. During early development of the pool, wells which encountered the top of the Yates higher than 520 feet above sea-level found only gas in the upper part of the upper pay zone. Wells which encountered the top of the Yates above 550 feet above sea-level found only gas in both the upper and lower members of the upper pay zone (Fig. 4).

An intermediate dolomite member separates the upper Yates and lower Yates pay zones, and is present in every well in the pool which was drilled deep enough to penetrate it. This intermediate member consists of about 60 feet of thin-bedded dolomite, gray and green shale, some red shale, and red and green sandy shale. Generally there is more red coloration in the shale east of the structural axis of the pool. Some anhydrite is present in this member east of the productive area of the pool. No production has been found in the dolomite member in the Payton pool.

The lower pay section comprises the lower 90 feet of the Yates sand below the intermediate dolomite member and above the Seven Rivers formation. The lower pay of the Yates sand encountered in the pool contains more sand free of shale and sandy shale and is coarser grained than sand beds in the upper pay zone. Very little shale or sandy shale is present in the lower pay zone near the top of the structure, but within $\frac{1}{2}$ mile east of the structural axis the sand beds grade into sandy shale, and 2 miles east of the axis the entire lower pay section has graded into red shale with streaks of red sandy shale and anhydrite. The actual thickness of oil-saturated sand in the lower pay zone varies from 0 to 34 feet (Fig. 5). The thickness map as drawn shows only oil-saturated sand, and does not reflect total sand thickness over the axis of the structure, but does reflect the eastern limit of sand at the zero-thickness contour on the east side of the pool. Oil and gas production is limited eastward by lack of porosity and permeability in the lower Yates section, rather than by structural position of the wells.

In general, there is more sand in both pay zones of the Yates section on the west side of the structural axis of the pool than on the east side. The individual sand beds grade into sandy shales and shale eastward across the pool. Anhydrite is present in the upper and lower members of the Yates sand east of the productive limits of the pool. Presence of shale and anhydrite reduce the porosity and permeability of the pay zones in the Yates sand, and the wells drilled more than $\frac{1}{2}$ mile east of the axis of the structure fall short of commercial production (Fig. 6).

Structure and Geologic History

The structure of the Payton pool in its present form is a northwestward-

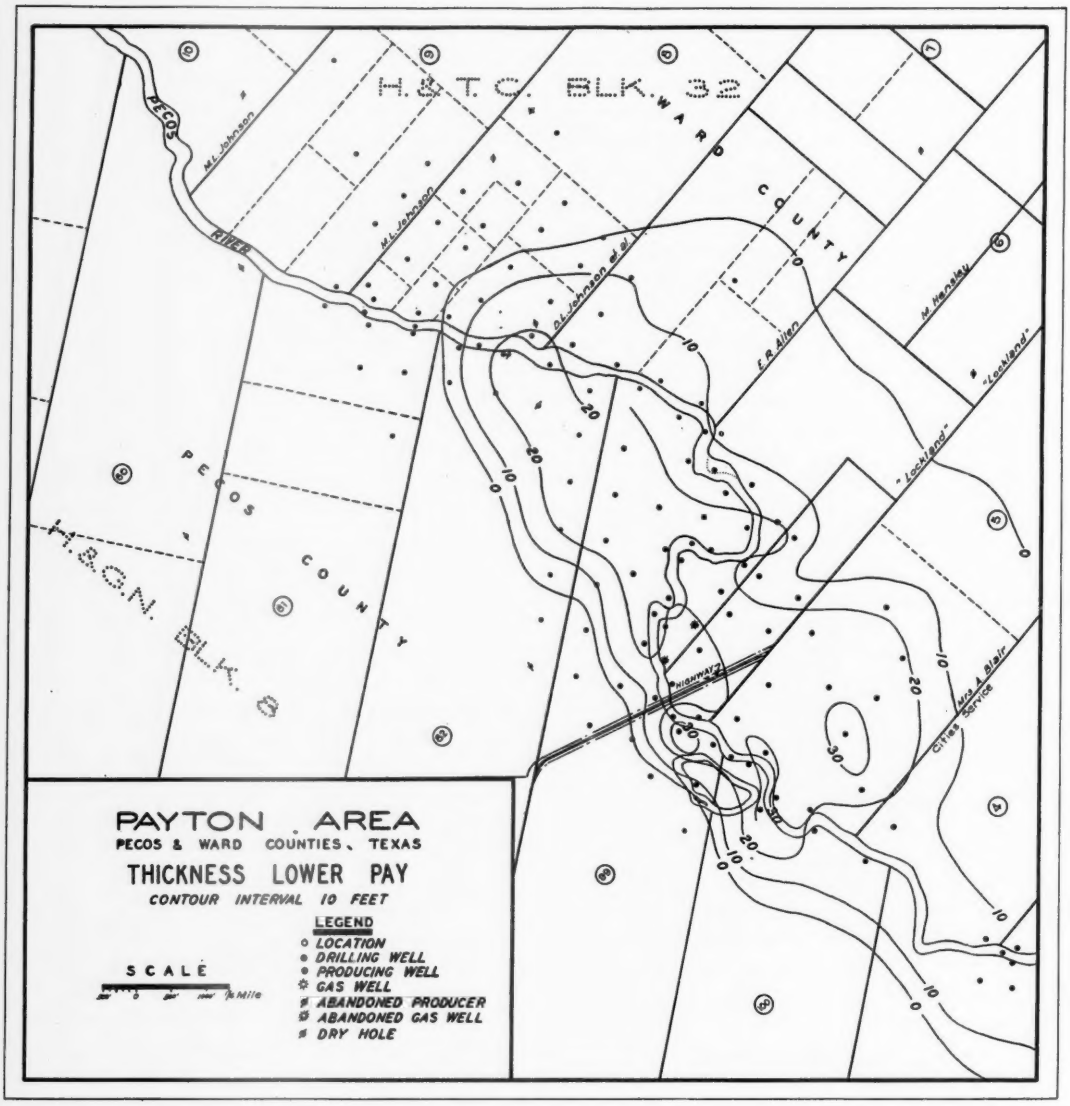


FIG. 5.—Isopach map of Payton pool showing thickness of oil-saturated sand, lower pay zone.

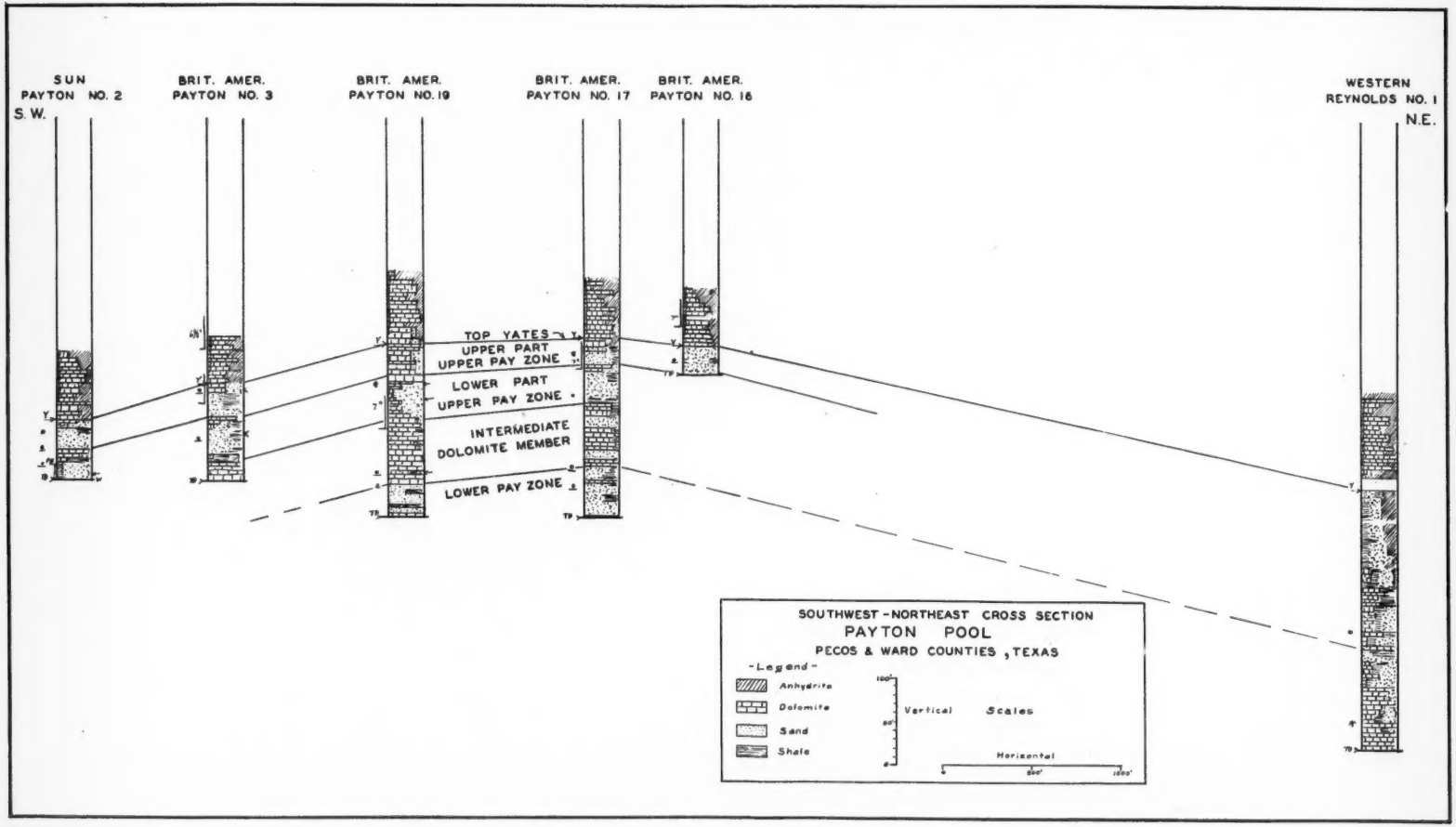


FIG. 6.—Southwest-northeast section, Payton pool.

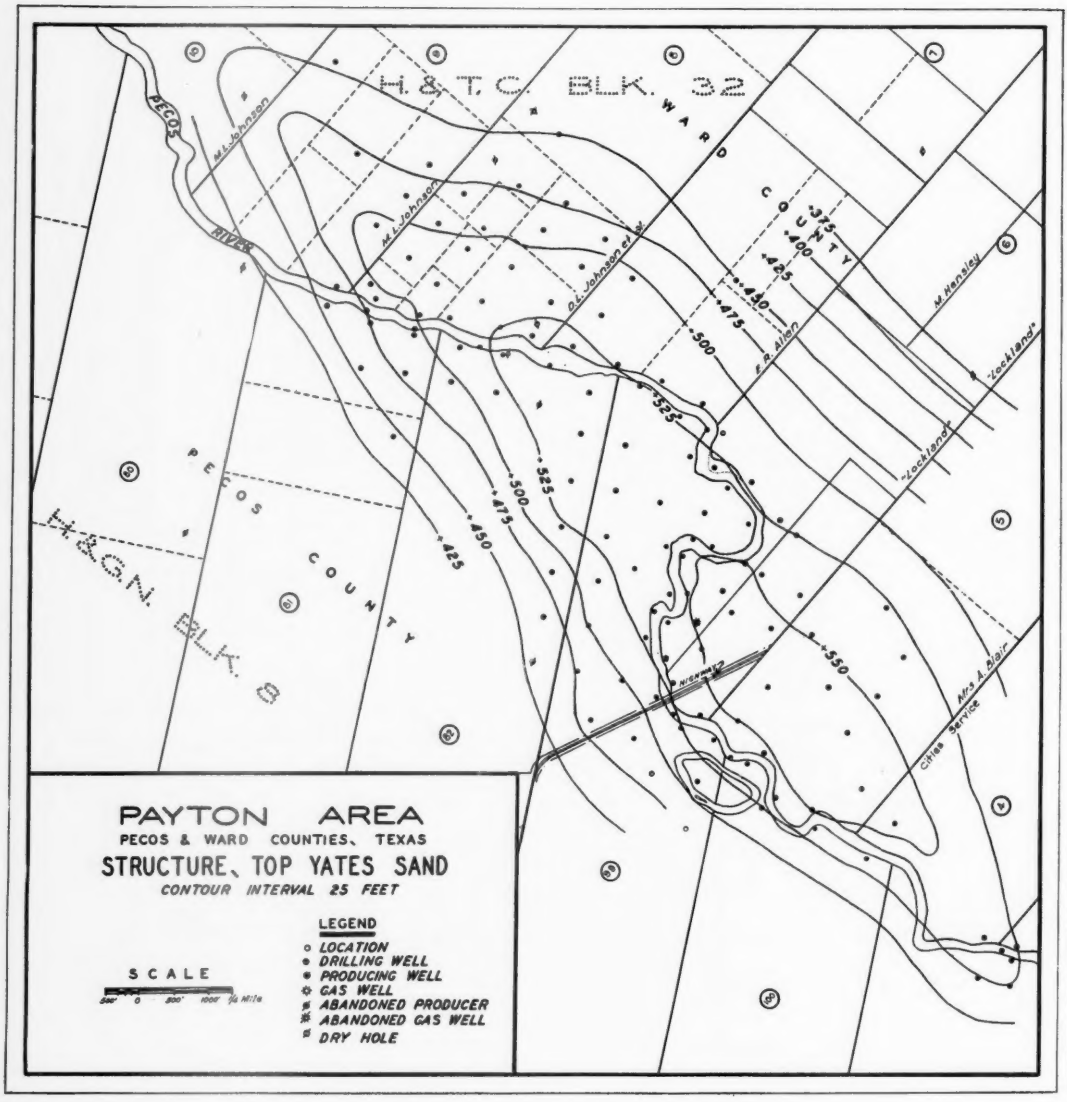


FIG. 7.—Structure-contour map drawn on top of Yates sand, Payton pool.

plunging anticline which has 40 feet of closure. The beds dip 300 feet to the mile on the west side of the structure, and 200 feet to the mile on the east side (Fig. 7).

At the time of deposition of the lower part of the Yates sand, the area west of the area of the pool was receiving vitasaline deposition of the reef zone, as defined by Lang,[5] and the area included in the pool was receiving penesaline deposition of the back-reef zone. A short distance east of the pool, saline deposition was taking place. A slightly elevated barrier is inferred immediately east of the present structural axis west of, and against which, the relatively clean sand of the lower pay section was deposited. Depth of water was probably slightly greater, and the water was less saline, west of this local barrier, accounting for sand, free of anhydrite and red shale, than east of the barrier where red sandy shale and anhydrite were deposited. The area of the Payton pool apparently was near the boundary between penesaline and saline deposition during lower Yates time.

In middle Yates time, the area was more deeply submerged and deposition of dolomitic limestones, approaching the vitasaline conditions of Lang, occurred in the area.

In upper Yates time, conditions were repeated which prevailed during lower Yates deposition, and again fairly clean sand was deposited in the west part of the area while sandy shale and anhydritic sand were deposited on the east.

Following the end of Yates deposition, the area received the penesaline deposits of the Tansill, consisting of anhydritic dolomites and anhydrite.

The structure continued to form during Salado time, as evidenced by the thin Rustler to Yates interval over the axis of the structure shown in Figure 8.

The top of the Rustler is essentially flat over the pool itself, but a slight westward tilting west of the pool occurred in post-Rustler time.

Production

Wells in the Payton pool have surface elevations of about 2,430 feet. The top of the Yates sand is encountered at 1,875 feet, high on the structure, and as low as 1,970 feet on the west flank. Most wells are completed at about 2,100 feet.

Initial production from early wells in the pool varied from 35 to 305 barrels per day, natural flow. The best wells are located immediately east of the axis where both the upper and lower pay sections were penetrated above the water level, and where more favorable sand conditions are found. Most of the wells have been shot with nitroglycerine and production was increased in the ratio of 3 or 4 to 1, or from 100 to 800 barrels per day, flowing. The original water level on the west side of the axis was at plus 275 feet. Low wells on the west flank of the structure could penetrate only the upper pay zone above water and were generally light wells. The original water level on the east side of the axis was at plus 325 feet;

[5] Walter B. Lang, "The Permian Formation of the Pecos Valley of New Mexico and Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 7 (July, 1937), p. 886.

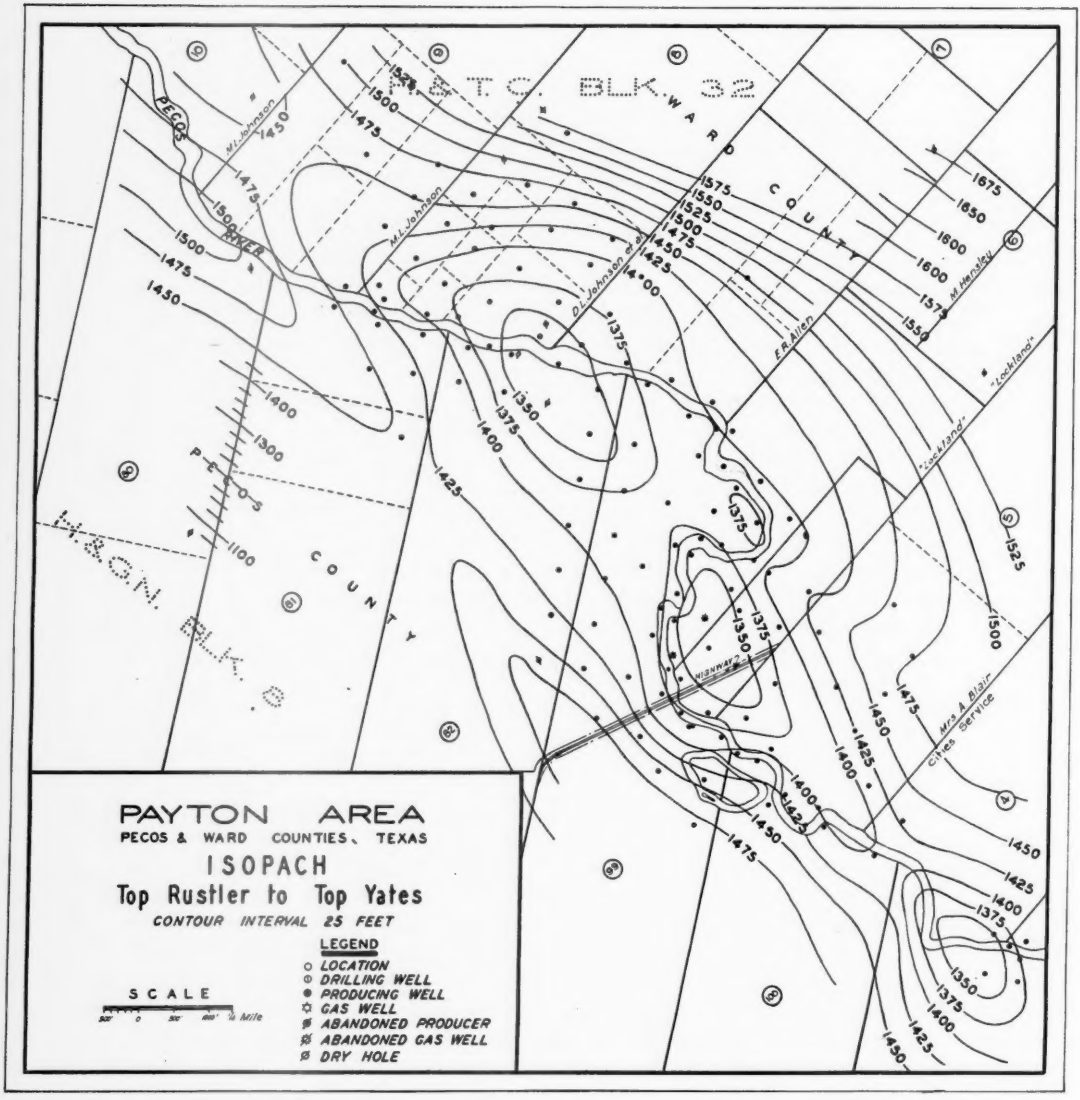


FIG. 8.—Isopach map of Payton pool showing thickness between top of Rustler formation and top of Yates formation.

hence only high wells could take maximum penetration of the lower pay zone and stay above water.

There was an original gas cap under high pressure in the pool. At least three wells encountered gas with sufficient volume and pressure to blow out during rotary drilling. One well gauged 15 million cubic feet of gas under 1,100 pounds pressure at 2,000 feet. Where casing was cemented below this high-pressure gas, gas-oil ratios were held below 1,000 cubic feet per barrel. In a few wells, the casing was cemented above the base of the gas zone and gas-oil ratios in excess of 5,000 cubic feet per barrel resulted, necessitating remedial work. During early development of the pool, wells which encountered the top of the Yates above plus 520 feet found only gas in the upper part of the upper pay zone. Wells which encountered the top of the Yates above plus 550 feet found only gas in the entire upper pay zone. Two wells at the top of the structure found gas in the top part of the lower pay zone.

Original bottom-hole pressures were 1,014 pounds per square inch in the upper pay zone at plus 500 feet, and 1,132 pounds per square inch in the lower pay zone, also at plus 500 feet. A bottom-hole-pressure survey as of June 1, 1939, showed an average bottom-hole pressure of 836 pounds per square inch. Cumulative production to June 1, 1939, was 486,180 barrels, or 2,548 barrels produced per pound drop in bottom-hole pressure. A second bottom-hole-pressure survey on September 1, 1940, showed an average bottom-hole pressure of 412 pounds per square inch. Cumulative production from June 1, 1939, to September 1, 1940, was 1,206,000 barrels, or 2,844 barrels produced per pound drop in bottom-hole pressure.

ANALYSIS OF CORE FROM BRITISH-AMERICAN OIL PRODUCING COMPANY'S PAYTON NO. 8

		Saturation % Cc. of oil Cc. of pores		*Porosity in Per Cent*	*Permeability in Millidarcys*
		Oil	*Water*		
Upper pay zone	a	8.96	63.8	17.4	.2
	b	11.5	54.2	27.0	34.1
	c	14.1	19.9	24.6	No sample
	d	27.5	85.4	15.2	.5
Intermediate dolomite	e	18.0	45.7	24.4	16.7
	f	24.0	49.6	21.3	19.3
Lower pay zone	g	18.3	49.2	24.5	No sample
	h	20.8	55.4	20.9	2.9
	i	10.9	61.4	18.9	17.7

On September 1, 1940, the Payton pool had produced 1,692,180 barrels of oil from 134 wells on 1,325 acres, for an average production of 12,627 barrels per well, and 1,280 barrels per acre. Ultimate production for the pool, based on cumulative production versus decline in bottom-hole pressure, is calculated to be 3,500,000 barrels. This figure indicates an average production of 2,640 barrels per acre, and 26,100 barrels per well. Volume of oil-saturated sand in the upper and lower pay zones combined totals 34,591 acre feet, determined by planimeter measurement of pay thickness from the pay-thickness contour maps. This indicates a recovery of 100 barrels per acre foot of saturated sand.

Water encroachment has not kept pace with withdrawal of oil from the reservoir. Gas expansion is the principal force in moving oil to the well bores.

Original gravity of the oil in the upper pay zone was 36°–37°, and in the lower pay zone 34°–35°. Gravity of the oil in both the upper and lower pay zones decreased more than 1° by the time the pool had produced 1,692,000 barrels to September 1, 1940.

DRILLING AND PRODUCTION METHODS

The early wells in the Payton pool were drilled with cable tools. Surface pipe was set through the upper fresh-water sands at about 100 feet. Water was encountered in the Rustler formation between 600 and 750 feet, and $8\frac{1}{4}$-inch casing was generally set below this water. The hole was then drilled through the Salado and to the Tansill formation above the Yates, and oil string, usually $6\frac{5}{8}$-inch, cemented at about 1,900 feet. The hole was generally loaded with water until the oil pay zone was reached, then unloaded and drilled to total depth. After flowing test or fill-up test, the well was shot with nitroglycerine opposite the pay section before running tubing. Most wells cleaned themselves after the shot, although some wells had to be cleaned out before being put on production.

Most of the later wells, and especially those wells high on structure, were drilled with small portable rotary equipment, either gasoline or deisel powered. In rotary wells, conductor pipe was cemented below the fresh-water sands. In some wells, the spudding and setting of surface pipe was done with small spudders, and rotary tools were then used to the top of the Yates sand. Samples were examined on the well to determine gas-oil contact, which might occur at various depths in the top 150 feet of the Yates section. When the gas-oil contact was determined, the hole was conditioned, and the production string, usually $6\frac{5}{8}$-inch, but in some wells $5\frac{1}{2}$-inch, was cemented below the gas zone. The plug was drilled with cable tools and drilling proceeded to the total depth. The wells were generally shot while the cable-tool unit remained on the location. In many wells, clean-out work with cable tools was necessary after shooting.

In a few wells the plug and the pay section of the Yates sand were drilled by the Beckman process of reverse circulation.

Wells were drilled on an average spacing of 10 acres per well. Various lease ownership of irregular tracts caused several wells to be drilled within 50 feet of adjacent lease lines.

In the early life of the pool the wells received a flat per-well allowable. This was modified in June, 1939, when wells were prorated 50 per cent on acreage and 50 per cent on a per-well basis.

On September 1, 1940, 40 wells had a natural flow, 29 wells were on gas lift, 50 wells were pumping, and 10 wells were dead.

ACKNOWLEDGMENT

The writer is indebted to the British-American Oil Producing Company for permission to publish this report. Thanks are due to Ronald K. DeFord and to E. Russell Lloyd for many helpful suggestions.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 26, NO. 10 (OCTOBER, 1942), PP. 1647-1655, 1 FIG.

AMOURA SHALE, COSTA RICA[1]

PAUL P. GOUDKOFF[2] AND WILLIAM W. PORTER II[3]
Los Angeles, California

ABSTRACT

In Talamanca Province on the Caribbean side of Costa Rica, microfauna in strata from the Amoura River a few meters from the mouth of Uscari Creek are lower Miocene or Oligocene in age, and are older than the Uscari formation as it is known from the publications of Olsson and Woodring. Some qualification is suggested about future correlations with the Uscari formation because of the difference in age between strata of the Uscari-Amoura area in the field (not listed by Olsson or Woodring), and strata in other localities ascribed to the Uscari formation in the literature. The microfauna has a marked affinity to that from Manta, Ecuador, and also to that of the Zemorrian stage of the California Miocene.

Another faunule from the Pacific side found on the end of the Nicoya Peninsula between Cape Blanco and Ballena Bay represents littoral sediments of Miocene age, probably younger than the beds sampled on the Amoura River.

Numerous papers referring to the Tertiary of the Isthmian region from Darien to Nicaragua have appeared from 1870 to the present, but most of the literature is prior to the time of efficient development of micropaleontology as a means of correlation. The results of all literature to 1935 are discussed by Schuchert[4] and a complete bibliography is given.

USCARI SHALE

A Miocene formation in Costa Rica and western Panama was described by Olsson[5] in 1922 and Redfield[6] in 1923. In 1924, Vaughan[7] regarded the Uscari fauna important as indicating a pre-Gatun Miocene formation in the area, and in 1928 Woodring[8] gave a résumé of previous writings and information on faunal collections.

The Uscari shale is unconformably overlain by the Gatun formation, and Woodring correlates the seaward facies of the Gatun with the Bowden of Jamaica which he considers Miocene, and probably middle Miocene. He gives locations of the Costa Rican and western Panama Miocene collections as follows: Puerto Limón, Rio Banana, Rio Betey (Biscay-?), Rio Estrella and tributaries, "several small streams entering the Caribbean Sea near Cahuita and Puerto

[1] Manuscript received, March 11, 1942.

[2] Consulting geologist, Subway Terminal Building, 417 South Hill Street.

[3] Millard Geophysical Co., 9730 Wilshire Boulevard, Beverly Hills.

[4] Charles Schuchert, *Historical Geology of the Antillean-Caribbean Region*, John Wiley and Sons, New York (1935).

[5] A. A. Olsson, "The Miocene of Northern Costa Rica with Notes on Its General Stratigraphic Relations," *Bull. Amer. Paleontology*, Vol. 9, No. 39, Pts. I and II (1922).

[6] Arthur H. Redfield, "The Petroleum Possibilities of Costa Rica," *Econ. Geol.*, Vol. 18 (1923), pp. 354–81.

[7] T. W. Vaughan, "Criteria and Status of the Correlation and Classification of Tertiary Deposits," *Bull. Geol. Soc. America*, Vol. 35 (1924), p. 736.

[8] W. P. Woodring, "Miocene Mollusks from Bowden, Jamaica," *Carnegie Inst. Washington Pub. 385* (1928), pp. 68–73.

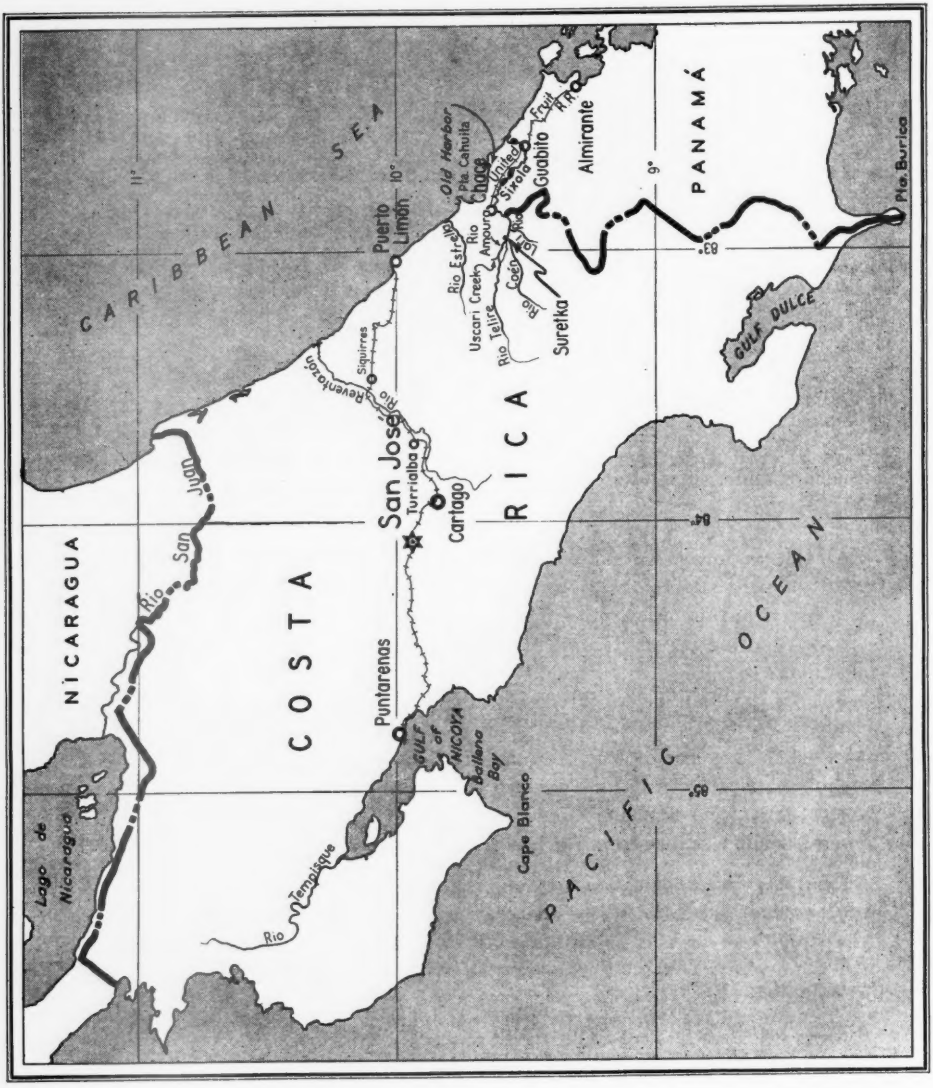


FIG. 1.—Map of Costa Rica, showing locations mentioned in text.

Viejo (Old Harbor) between Rio Estrella and Punta Mona," islands in Almirante Bay, Sapote on the Rio Reventazón (Gabb locality), and from the south part of Talamanca basin on "Oronli Creek," a tributary of Rio Uren which flows northerly into the Rio Sixola. The lower Rio Sixola forms the Panama-Costa Rica boundary. He suggests that the Gabb locality at Sapote on Rio Reventazón might be regarded as the type Miocene locality of Costa Rica.

A. A. Olsson and R. A. Terry have done considerable work in the area and Olsson's later opinion (1934) as quoted by Schuchert is that the lower part of the Uscari shale is Oligocene. R. T. Hill and D. F. Macdonald, as quoted by Redfield at page 364, also suggest Oligocene age for at least a part of the Uscari.

Woodring points out that of all the Uscari collections available to him, none is from the type locality. The type locality described by Redfield is 7 miles westerly from Suretka in the area where Uscari Creek enters the Amoura River, but he lists no fossils.

Porter visited this locality in 1939 and the faunal studies by Goudkoff are described in this article.

In view of the existing literature which lists no fossil localities from Uscari Creek, and of the lack of geographical importance of the small, almost lost Uscari Creek (it was formerly a few hundred meters from a United Fruit railway, but is now in an abandoned region 25 miles above rail head, nearly reclaimed by jungle), Woodring's suggestion that the Sapote area on the River Reventazón (near main line of Limón-San José railroad) be considered the type Miocene locality, is a very practical one.

Schuchert's reference (top of page 604) to fauna from the type locality of the Uscari, while discussing Woodring's studies, may refer to the Sapote area, as Woodring had no collections from Uscari Creek.

MOLLUSKS

Because Olsson's paper (1922) is not easily available, his list of Uscari fauna is given here. Most of the 334 species described are from the Gatun formation which is younger, but the following occur in the Uscari. Names in brackets indicate localities.

Scaphella costaricana, n. sp. [Cocles Creek]; *Fasciolaria tulipa* (*Linnaeus* variety) [Port Limón]; *Ptychosalpinx ? dentalis*, n. sp. [Coco Plum, Panama, and Rio Cocles]; *Alectrion merenda*, n. sp. [Old Man Sam Creek]; *Sistrum nodulosum*, C. B. Adams [Red Cliff Creek]; *Sconsia cocleana*, n. sp. [Rio Cocles, near Old Harbor]; *Malea elliptica* Pilsbry and Johnson [Red Cliff Creek]; *Strombus pugiloides* Guppy [Sapote]; *Chlorostoma costaricansis*, n. sp. [Red Cliff Creek]; *Dentalium uscarianum*, n. sp. [Coco Plum, Margarita—Old Harbor trail, Comadre Creek, *et cetera*]; *Pteria inornata* Gabb [Old Harbor]; *Clementia dariena* Gabb [Sapote].

Schuchert, apparently from a communication from Olsson, also lists the following from the Uscari: *Amusium lyonii, Arca dariensis, Cancellaria* (*Aphera*) *islacolonis*, and *Neverita nereidis*, in addition to several of the foregoing list.

WELL SAMPLES

Katherine Van Winkle Palmer (see reference 23 at end of article,[9] reporting on material "from a portion of well section at Cahuita, Costa Rica, in the Uscari shales of Lower Miocene age at depths of 3,818′ and 3,861′)," says, "material represents a lower portion of the shales than heretofore described." She gives a list of the species listed by Olsson from the Uscari shales and adds the species from near Old Harbor in the upper shales. Also added are species of Foraminifera "from a dark gray, calcareous, volcanic compact sand from MacDonald and Nigua Creeks." Referring to the presence of fairly abundant Nummulites and a single specimen of *Lepidocyclina*, Miss Palmer assumes that the age of the Nigua Creek and MacDonald Creek sediments is Oligocene. The localities referred to in the text are (1) Cahuita well, about 22 miles southeast of Limón, 82° 50′ W., 9° 45′ N.; (2) MacDonald Creek, 7 miles south of Guabito, 82° 40′ W., 9° 25′ N.; (3) Nigua Creek, 5 miles west of Alamirante, 82° 27′ W., 9° 20′ N.

H. D. Hedberg in his discussion of Foraminifera of the Carapita formation, remarks (2, p. 689) that the material from the Cahuita well described by Katherine Van Winkle Palmer appears to be younger than the Carapita formation. About the latter, Hedberg concludes that "it must lie between upper Eocene and lower Miocene, and the bulk of the evidence seems to point to upper Oligocene" (2, p. 695).

AMOURA SHALE

The samples herein studied by Goudkoff were collected by Porter in the region of Talamanca, western Costa Rica, about 7 miles westerly from Suretka. Suretka is shown as a town on most maps, but since abandonment of the upper Talamanca area by the United Fruit Company several years ago, Suretka now consists of one small ranch and one man. The railways have been abandoned above Chace and the rights-of-way are almost obliterated by the encroaching jungle growth. Near Suretka the rivers Uren, Coen, Lari, and Telire unite to form the Sixola. The northernmost of these rivers is the Telire which splits into two principal branches 12 kilometers westerly (upstream) from Suretka. These two branches diverge and flow around a cigar-shaped area, to join again near Suretka, and the northerly of these is known as the Rio Amoura. About 7 miles westerly from Suretka, Uscari Creek empties from the north into the Amoura, 2–3 kilometers downstream from where the Amoura leaves the Telire.

Samples were collected from the north bank of the Amoura, about 200 meters

[9] All further references to the literature on Foraminifera are indicated in the text by numbers in parenthesis which refer to the numbers of the listed references at the end of this article.

upstream from the mouth of Uscari Creek. A conspicuous shale outcrop occurs at an elbow bend in the Amoura, and fairly recent rapid cutting has exposed fresh shale. This locality, on the small map at page 363 of the Redfield article referred to, would fall near the "*R*" of "*R* Amoura," under the "O" of "Costa Rica." The shale found up Uscari Creek is similar but does not afford fresh samples. From published descriptions available, the writers conclude that the collection is from the type locality of the Uscari shale.

The formation sampled is fine gray clay, or mud, shale distinctly bedded in fresh outcrops, but inclined to slump and become formless in older exposures. It rapidly weathers to tan or brown.

It would appear that there is no Uscari shale as it is known from published faunal descriptions at its type locality. However, this point seems immaterial, as the creek is unimportant in an unpopulated area, and as no collections from the type locality are involved in published correlations and data on the Uscari formation. It may be well to take Woodring's suggestion and move the type locality to some place where the Uscari fauna has been collected. He suggests Gabb's Sapote area on the Rio Reventazón.

It is proposed that the shale here studied be called the Amoura shale. Future work may decide whether this shale shall be the Amoura shale member of the Uscari formation, or whether the Amoura shale and the younger Uscari of previous literature should be distinguished by a more important break.

Samples collected on Amoura River contain a foraminiferal assemblage that shows a marked affinity with the microfauna from Manta, Ecuador, described by J. J. Galloway and Margaret Morrey (5), and also with that of the Zemorrian stage of the California Miocene (14).

The age of the Ecuador fauna was first determined by Galloway and Morrey as upper Eocene. Later, J. A. Cushman ascribed to the same fauna the Miocene age (7). And still later J. B. Dorr arrived at the conclusion that the fauna in question is typical of the Oligocene of the Latin American Tertiary (6).

A somewhat similar uncertainty exists about the age of the Zemorrian stage of the California Tertiary, since Hubert G. Schenck has shown that the Vaqueros formation (representing a part of the Zemorrian stage) may well be referred to the Oligocene (24).

According to H. D. Hedberg (2, pp. 689 and 693), the Ecuador fauna appears to be younger than the upper Eocene, and older than the middle Miocene. As to the Zemorrian stage of California, Hedberg believes that it may be considered as early upper or late middle Oligocene.

A comparative study of the foraminiferal content of a sample from the Amoura River suggests that the sample comes either from the lower Miocene or from the Oligocene. Abundance of *Planulina* and *Robulus*, together with abundant *Orbulina* indicates deposition in temperate waters at a depth above the continental shelf and under open-sea conditions.

The foraminiferal species found in the samples and reference to the descriptions with which each of the species has been compared are here listed.

	References	
	Number	*Page*
Bolivina cf. *B. acerosa* Cushman		
(Miocene, Gurabo formation, Santa Dominica)	1	54
Bolivina cf. *B. aenariensis* (*Costa*) var. *carapitana* Hedberg		
(Oligocene, Carapita formation, NE. Venezuela)	2	676
Bolivina cf. *B. floridana* Cushman	3	46
(Miocene Choctawhatchee formation of Florida; Miocene, lower Temblor, California; Oligocene, San Lorenzo formation, California)	4	9
	9	93
Bolivina cf. *B. pisciformis* Galloway and Morrey	5	36
(Oligocene-?-Miocene of Manta, Ecuador; Miocene of Venezuela and Trinidad; lower Miocene, California)	7	93
	14	279
Bulimina cf. *B. rinconensis* Cushman and Laiming	8	107
(Lower Miocene and Oligocene, California)	9	62
Cassidulina crassa d'Orbigny (Miocene, Venezuela)	7	100
Cassidulinoides sp.		
Cibicides cf. *C. ungeriana* (d'Orbigny)		
(Oligocene?, Miocene, Manta, Ecuador)	5	31
Clavulina communis d'Orbigny		
(Lower Miocene, California)	11	38
Dentalina cf. *D. communis* d'Orbigny		
(Lower Miocene, California)	4	3
Dentalina multilineata Bornemann		
(Oligocene, Alazan Clay, Mexico)	12	152
Dentalina roemeri Neugeboren		
(Miocene, California)	14	214
Eponides umbonata (Reuss)		
(Upper Eocene, Cooper marl. South Carolina; Eocene, Chapapote formation, Mexico; Oligocene-?-Miocene of Manta, Ecuador; general range from Oligocene to Recent)	16	48
	15	15
	5	26
Globigerina bulloides d'Orbigny		
(Long range species; recorded in Tertiary of Manta, Ecuador)	5	9
Globigerina conglomerata Schwager		
(Long range species; recorded in Tertiary of Manta, Ecuador, and in lower to upper Miocene of California)	5	9
	14	143
Haplophragmoides sp.		
Lagena striato-punctata Parker and Jones		
(Miocene, Choctawhatchee formation, Florida)	3	32
Lamarkina sp.		
Liebusella pozonensis Cushman and Renz var. *crassa* Cushman and Renz		
(Upper Oligocene to middle Miocene, Venezuela)	10	9
Marginulina (*Robulus*) *subaculeata* (Cushman) var. *glabrata* (Cushman)		
(Later Tertiary of Trinidad and Venezuela; Jewett silt, Miocene, lower Saucesian stage, California)	7	85
Marginulina subbulata Hantken	7	85
(Oligocene, Alazan clay, Mexico and Venezuela; lower Miocene, California; Oligocene; San Lorenzo formation, California)	8	99
	14	145, 208
	9	58
Nodosaria ewaldi, Reuss		
(Oligocene, Alazan clay, Mexico; Eocene, Poway conglomerate, California)	12	153
	19	56
Nodosaria holserica Schwager		
(Eocene-Miocene, Manta, Ecuador)	5	17

	References	
	Number	*Page*
Nodosaria koina Schwager	9	29
(Oligocene, San Lorenzo formation, California; Miocene, California)	8	100
Nodosarella camerani (Dervieux)		
(Tertiary of Manta, Ecuador)	5	41
Orbulina universa, d'Orbigny		
(Long range pelagic form)		
Planulina cushmani (Barbat and von Estorff)		
(Lower Miocene, California)	20	173
Plectofrondicularia aff. *californica*		
Cushman and Stewart, much flattened variety (Type recorded in Tertiary of Ecuador, and Venezuela, also in Miocene and lower Pliocene of California; similar variety occurs also in early upper Eocene of California)	7 14	90 239
Quinqueloculina sp.		
Robulus barbati Cushman and Hobson		
(Oligocene, San Lorenzo formation, California)	9	57
Robulus mayi Cushman and Parker	4	2, 3
(Lower Miocene, Temblor and Vaqueros formations, California)	2	124
	4	2
Robulus cf. *R. taettowata* Schwager		
(Tertiary, Manta, Ecuador)	5	21
Saracenaria acutauricularis (Fichtel and Moll)	7	88
(Tertiary, Venezuela; lower Miocene, California)	14	222
Sphaeroidina variabilis Reuss	7	101
(Tertiary, Venezuela; lower Miocene, California)	20	173
Textularia mississipiensis Cushman		
(Tertiary, Venezuela)	7	79
Uvigerina cf. *U. gardnerae* Cushman and Applin var. *cubana* Hadley		
(Middle Tertiary, Carapita formation, NW. Venezuela)	2	27
Uvigerina hispida Schwager	5	39
(Tertiary of Ecuador, Trinidad and Venezuela; lower Miocene, California)	7 14	95 295
Uvigerina cf. *pigmaea* d'Orbigny, after Nuttall		
(Oligocene)	22	81

PACIFIC COAST

On the end of Nicoya Peninsula, between Cape Blanco and Ballena Bay, gently dipping Miocene beds are exposed, resting on basaltic type basement rock. The exposed section from the bottom to the top of sea cliff consists of basal conglomerate, clayey buff shale, slabby soft ripple-marked sandstone, soft brown sandstone, brown shale, and fairly soft blue-gray-buff shale, and pebbly conglomerate. The total exposed section in cliff has a thickness of about 100 feet. The occurrence is about 3 miles toward Cape Blanco from the southwest side of the entrance to Ballena Bay and is easily seen from a boat.

Two samples collected from the described section represent buff siltstone and bluish gray clayey shale full of rounded fragments of molluscan shells and of small pebbles. The microfauna found in washed material of the samples includes the following species.

	References	
	Number	*Page*
Amphistegina sp. (most abundant species in the samples)		
Bolivina marginata Cushman var. *multicostata* Cushman	17	25
(Miocene of Florida)	31	7
Cassidulina subglobosa H. B. Brady		
(Tertiary of Ecuador, Venezuela, and Trinidad)	7	100
Cibicides choctawensis Cushman & McGlamery		
(Oligocene of Alabama)	25	111
Ellipsonodosaria verneuli (d'Orbigny) var. *paucicostata*		
(Galloway and Morrey). (Tertiary of Ecuador; Oligocene-lower Miocene	4	97
of Porto Rico)	26	440
Elphidium sp. (abundant in samples)		
Eponides cf. *affinis* (Czjzek)		
(Lower Miocene, upper Zemorrian of California)	8	114
Globigerina trilocularia d'Orbigny	5	10
(Tertiary of Ecuador; middle Oligocene of Porto Rico)	26	414
Gyroidina cf. *laevis* d'Orbigny		
(Tertiary of Ecuador)	5	27
Gyroidina soldanii d'Orbigny		
(Tertiary of Ecuador, Venezuela and Trinidad)	7	98
Nonion sp. identical with *N.* cf. *scapha* (Fichtel and Moll)		
as pictured by Cushman and G. D. Hanna from Eocene near Coalinga, California	27	224
Planulina cf. *cocoaensis* Cushman		
(Upper Eocene of Alabama)	28	76
Pyrgo affinis d'Orbigny		
(Tertiary of Vienna Basin)	29	265
Quinqueloculina seminulum (Linné) (abundant in sample)		
Robulus aff. *plummerae* Cole		
(Upper Eocene, Chapapote formation of Mexico; upper Oligocene-lower	15	8
Miocene of Porto Rico)	26	350
Uvigerina cf. *auberiana* d'Orbigny		
(Tertiary of Trinidad and Venezuela; Oligocene of	7	95
Venezuela)	22	81
Uvigerina gardnerae Cushman (?)		
(one poorly preserved specimen resembling *U. gardnerae* described by Cushman from upper Eocene of Texas)	30	175

It is interesting to note that among the microfossils listed, one group, including all of the most abundant species (*Amphistegina, Bolivina, Elphidium, Eponides*, and *Quinqueloculina*) are of white color, whereas the species *Nonion, Planulina, Pyrgo, Robulus*, and *Uvigerina gardnerae* (each represented by a single specimen) are of distinctly different brown color. Considering each of the two groups separately, one may notice that the white forams making up the bulk of the assemblage, suggest the Miocene age, very likely somewhat younger than the microfauna of the Amoura River, but probably not younger than the middle Miocene. The latter assumption is based on the presence of *Bolivina marginata* var. *multicostata*, the size and well developed longitudinal costae of which show a great similarity to the variety of the species typical of the middle Miocene Shoal River formation of Florida (31, p. 30, and lowest right figure on Pl. 7).

As to the scarce specimens of brown-colored Foraminifera, they may be thought to be reworked from an older formation (Oligocene or Eocene).

Abundance of *Amphistegina* and *Elphidium* in the samples from the Nicoya Peninsula indicates littoral conditions of deposition (warm shallow waters).

REFERENCES

1. CUSHMAN, J. A., "New Genera and Species of the Families Verneuilinidae and Valvulinidae and of the Subfamily Virgulininae," *Cushman Lab., Foram. Research Spec. Pub. 6* (1936).
2. HEDBERG, H. D., "Foraminifera of the Middle Tertiary Carapita Formation of Northeastern Venezuela," *Jour. Paleon.*, Vol. 11, No. 8 (1937).
3. CUSHMAN, J. A., "Foraminifera of the Choctawhatchee Formation of Florida," *Florida Geol. Survey Bull. 4* (1930).
4. CUSHMAN, J. A., and PARKER, FRANCIS L., "Miocene Foraminifera from the Temblor of the East Side of the San Joaquin Valley, California," *Contrib. Cushman Lab. Foram. Research*, Vol. 7, Pt. 1 (1931).
5. GALLOWAY, J. J., and MORREY, MARGARET, "A Lower Tertiary Foraminiferal Fauna from Manta, Ecuador," *Bull. Amer. Paleon.*, Vol. 15, No. 55 (1929).
6. DORR, J. B., "New Data on the Correlation of the Lower Oligocene of South and Central America with That of Southern Mexico," *Jour. Paleon.*, Vol. 7, No. 4 (1933), pp. 432–38.
7. CUSHMAN, J. A., "A Late Tertiary Fauna of Venezuela and Other Related Regions," *Contrib. Cushman Lab. Foram. Research*, Vol. 5, Pt. 4 (1929).
8. CUSHMAN, J. A., and LAIMING, BORIS, "Miocene Foraminifera from Los Sances Creek, Ventura County, California," *Jour. Paleon.*, Vol. 5, No. 2 (1931).
9. CUSHMAN, J. A., and HOBSON, H. D., "A Foraminiferal Faunule from the Type San Lorenzo Formation, Santa Cruz, California," *Contrib. Cushman Lab. Foram. Research*, Vol. 11, Pt. 3 (1936).
10. CUSHMAN, J. A., and RENZ, H. H., "New Oligocene-Miocene Foraminifera, from Venezuela," *ibid.*, Vol. 17, Pt. 1 (1941).
11. CUSHMAN, J. A., and BARBAT, WILLIAM F., "Notes on Some Arenaceous Foraminifera from the Temblor Formation of California," *ibid.*, Vol. 8, Pt. 2 (1932).
12. CUSHMAN, J. A., "Some Characteristic Mexican Foraminifera," *Jour. Paleon.* Vol. 1, No. 2 (1927).
13. NUTTALL, W. L. F., "Lower Oligocene Foraminifera from Mexico," *ibid.*, Vol. 6, No. 4 (1932).
14. KLEINPELL, R. M., *Miocene Stratigraphy of California* (Amer. Assoc. Petrol. Geol., 1938).
15. COLE, W. STORRS, "A Foraminiferal Fauna from the Chapapote Formation in Mexico," *Bull. Amer. Paleon.*, Vol. 14, No. 53 (1928).
16. CUSHMAN, J. A., "Upper Eocene Foraminifera of the Southeastern United States," *U. S. Geol. Survey Prof. Paper 181* (1935).
17. CUSHMAN, J. A., and CAHILL, EDGAR D., "Miocene Foraminifera from Coastal Plain of the Eastern United States," *ibid., 175-A* (1933).
18. CUSHMAN, J. A., "Mexican Species of *Marginulina*," *Contrib. Cushman Lab. Foram. Research*, Vol. 1, Pt. 3 (1925).
19. CUSHMAN, J. A., and DUSENBURG, A. N., JR., "Eocene Foraminifera of the Poway Conglomerate of California," *ibid.*, Vol. 10, Pt. 3 (1934).
20. BARBAT, W. F., and VON ESTORFF, F. E., "Lower Miocene Foraminifera from the Southern San Joaquin Valley, California," *Jour. Paleon.*, Vol. 7, No. 2 (1933).
21. CUSHMAN, J. A., and LEROY, L. W., "Microfauna from the Vaqueros formation, Lower Miocene, Simi Valley, Ventura County, California," *ibid.*, Vol. 12, No. 2 (1938).
22. CUSHMAN, J. A., and EDWARDS, P. G., "Notes on Oligocene Species of *Uvigerina* and *Angulogerina*," *Contrib. Cushman Lab. Foram. Research*, Vol. 14, Pt. 4 (1938).
23. PALMER, KATHERINE VAN WINKLE, "Foraminifera and a Small Molluscan Fauna from Costa Rica," *Bull. Amer. Paleon.*, Vol. 10, No. 40 (1923).
24. SCHENCK, HUBERT G., "What Is the Vaqueros Formation of California, and Is It Oligocene?" *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19 (1935), pp. 521–36.
25. CUSHMAN, J. A., and MCGLAMERY, W., "Oligocene Foraminifera from Choctaw Bluff, Alabama," *U. S. Geol. Survey Prof. Paper 189-D* (1938).
26. GALLOWAY, J. J., and HEMINWAY, CAROLINE E., "The Tertiary Foraminifera of Porto Rico," *Scientific Survey of Porto Rico and the Virgin Islands*, Vol. III, Pt. 4 (New York Acad. Sci., 1941).
27. CUSHMAN, J. A., and HANNA, G. DALLAS, "Foraminifera from the Eocene near Coalinga, California," *Proc. California Acad. Sci.* Ser. 4, Vol. V, 16, No. 8 (1927).
28. CUSHMAN, J. A., "Additional Foraminifera from the Upper Eocene of Alabama," *Contrib. Cushman Lab. Foram. Research*, Vol. 4, Pt. 3 (1928).
29. D'ORBIGNY, A. D., *Foraminifères fossiles du Bassin tertiarie de Vienne* (1846).
30. CUSHMAN, J. A., and APPLIN, E. R., "Texas Jackson Foraminifera," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 2 (1926).
1. CUSHMAN, J. A., and TODD, RUTH, "Statistical Studies of Some Bolivinas," *Contrib. Cushman Lab. Foram. Research*, Vol. 17, Pt. 1 (1941).

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 26, NO. 10 (OCTOBER, 1942), PP. 1656–1671, 11 FIGS.

PREPARATION OF LANTERN-SLIDE COPY[1]

CARL A. MOORE[2]
New York, N. Y.

ABSTRACT

The major defects in faulty lantern slides are usually: (1) the scale of lettering on the original copy is too small; and (2) the lines, letters, and figures are overcrowded on the original copy. These defects result in the projected image being illegible on the screen. As mechanical or photographic defects can be eliminated by reliable lantern-slide makers they are not discussed here.

A standardized procedure is presented for use in drafting maps, charts, tables, *et cetera*, for lantern-slide presentation. This procedure consists of a simple formula and a series of charts to illustrate the *minimum* letter and figure heights that should be used on the original lantern-slide material. The formula is based on the following three factors that control the legibility of lantern slides: (1) maximum size of lecture room, or maximum audience distance, (2) size or width of original lantern-slide copy, and (3) size or width of screen on which lantern slide is to be projected.

Illustrations of geological maps, cross sections, and electric logs have been prepared following the recommended formula.

The dimensions set forth here for original lantern-slide copy represent a figure and letter size appreciably larger than the minimum size employed for routine drafting work. This discussion of dimensions also supports the general conclusion that most original copy must be redrafted for lantern-slide reproduction in order to provide larger figure and letter sizes, if good results are to be secured.

INTRODUCTION

There is practically no published information available on the minimum requirements for the height of letters and figures on the original lantern-slide copy[3] which will insure legibility when projected on a screen. It is intended to present here, by formula, a standardized procedure and technique for use in drafting maps, charts, tables, *et cetera*, for lantern-slide presentation.

It is to be emphasized that the defects in lantern slides are attributable largely to faulty drawing techniques in the preparation of the original material. The procedures outlined here have been carefully checked over and lantern slides have been made up following the recommended formula. Upon projection these lantern slides were highly legible at the distances indicated by the formula for the given size of original material, size of screen, *et cetera*. This formula provides the quantitative answer of "how much bigger" lettering and figures must be in order to be legible for lantern-slide reproduction.

ACKNOWLEDGMENTS

The writer is indebted to the Standard Oil Development Company for permission to publish this report. Acknowledgment is hereby made to J. R. Hall and L. R. Joslin, of the Standard Oil Development Company, and F. M. Surface and

[1] Published with permission of the Standard Oil Development Company. Manuscript received, December 23, 1941.

[2] Research geologist, Standard Oil Development Company, 30 Rockefeller Plaza.

[3] In this paper there is a distinction between a *lantern slide* and *lantern-slide copy*. The *lantern slide* is the image, photographically imprinted on a glass plate or on a film mounted between glass plates, or held in a cardboard mount, which is placed in the projector. *Lantern-slide copy* is the material: chart, map, photograph, diagram, blueprint, and such, from which the lantern slide is made.

Stewart C. Malloy, of the Standard Oil Company of New Jersey, for their co-operation in preparing reports on methods employed by their departments in preparing lantern-slide copy.

Special thanks are due L. C. Sage, of the Standard Oil Development Company, for his assistance with the writing of many sections of the report, for his technical advice, and for his continued interest in the report. W. B. Spangler, of the Standard Oil Development Company, drafted the charts based on the formula, and assisted in proof-reading the manuscript.

TABLE I

CHARACTERISTICS OF DIFFERENT TYPES OF LANTERN SLIDES

Type of Slide	*Size in Inches*	*Weight of 25 Slides, in Ounces*	*Cubic Inches of Filing Space for 25 Slides*	*Material Required for 1 Slide*	*Remarks*
Glass: printed on glass plate	3¼×4	44	40.5	1 mask 1 cover glass 14½ inches of tape 1 sensitized plate	Emulsion protected Maintains focus Cracks frequently during projection Fragile
Glass: printed on glass plate	2×2	9	11.0	1 mask 1 cover glass 8 inches of tape 1 sensitized plate	Emulsion protected Maintains focus Can be projected indefinitely Durable but not unbreakable
Glass: printed on film; mounted between glass	2×2	10	11.5	1 double mask 2 cover glasses 8 inches of tape 1 film	Emulsion protected Will not maintain focus Film buckling often breaks glass
Film: mounted in cardboard (Kodaslides)	2×2	2	4.5	1 cardboard mount 1 film	Emulsion not protected against scratches Satisfactory and widely used for short-period projection Will buckle and lose focus after extended exposure in poorly ventilated lantern
Cellophane (Radio-mats)	3¼×4	These slides are good only for emergency projection			

TYPES OF LANTERN SLIDES

Several types of lantern slides can be made in both the 3¼-×4-inch and 2-×2-inch size. Characteristics of these slides are listed in Table I.

At present 3¼-×4-inch glass slides are accepted in the United States as standard. Due to the reduced cost, small filing space required, and the portability of the smaller equipment, the 2-×2-inch glass slides printed directly on the glass are being used more and more.

Figure 1 is an illustration of the standard United States lantern slide, measuring $3\frac{1}{4} \times 4$ inches, with a height-to-width ratio of about 0.8 to 1.0. Because of the necessary border mat and binding, the maximum size of the actual image on a standard lantern slide is about $2\frac{5}{8} \times 3\frac{1}{4}$ inches.

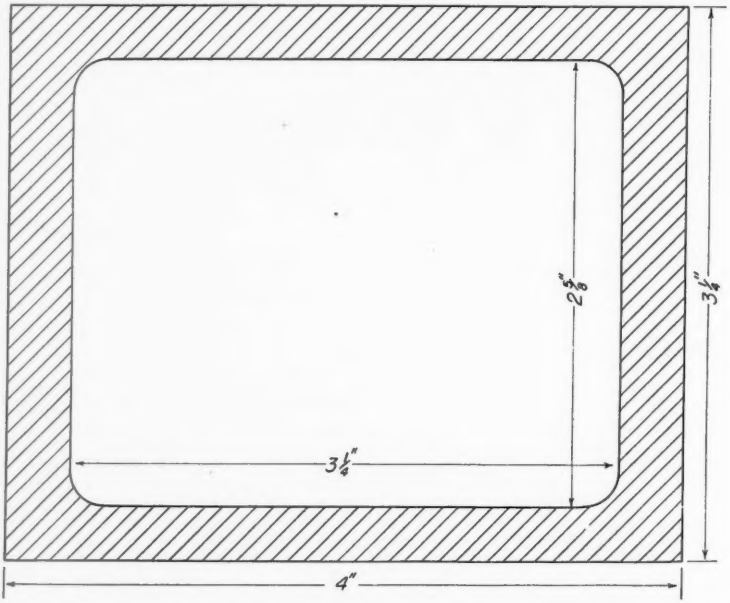


FIG. 1.—Illustration of standard United States lantern slide showing dimensions of slide and dimensions of actual image, allowing for necessary border mat and binding.

GENERAL TECHNIQUES

While lantern-slide projections are essential for the efficient presentation of many technical papers, it is to be realized that the slide is only an illustration. It presupposes an explanation by the speaker and usually can not be complete within itself. With this in mind the following general rules may be laid down.

1. The lantern slide should present one central idea and should be free from all lettering and lines that are not essential to a clear understanding of its message. The number of words on a chart should be held to a minimum (15–20 words, for example).

2. Supplementary data or formulas should not be shown unless positively necessary, in which case they should be isolated in position and enclosed by a light line border.

3. A ratio of 0.8 to 1.0 should be followed when comparing the vertical and horizontal dimensions on the original copy.

4. The visibility of parallel lines which are close together is about half of that of a single line with a wide, contrasting background. This is of interest because it aids in determining the approximate minimum width of line for the lettering.

5. The space between letters or rows of lettering should be at least twice the thickness of the drafted lines forming the letters.

6. Lines composing the ruling for charts may be made $\frac{3}{4}$ the width of the minimum single line and should be at least $\frac{1}{2}$ the width of any line drawn on the chart. It is not necessary that rulings on charts shall have 100 per cent visibility. It is more desirable that these lines shall be inconspicuous.[4]

7. In lettering lantern-slide copy with the standard lettering guides (Leroy or Wrico guides) a finer pen than is ordinarily used for lettering drawings should be used. The finer lines of the lettering make much clearer copy and keep the letters from "filling up" when the copy is reduced to lantern-slide size. Also the letters should be spaced farther apart to allow for better legibility when projected. *This is important.*

The following pens for standard lettering templates are recommended for preparing lantern-slide copy. These pens are finer than those ordinarily used in drafting work. See Table II.

TABLE II

RECOMMENDED PEN SIZES FOR STANDARD LETTERING TEMPLATES FOR USE IN PREPARING LANTERN-SLIDE COPY

Wrico Pen Number	*Leroy Pen Number*	*Nominal Letter Height (Inches)*	*Wrico Pen Number*	*Line Width (Inches)*
4 or 5	2 or 3	0.240	6	0.025
5	2	0.200	7	0.017
6	1	0.190		
6	1	0.175	*Leroy Pen Number*	
7	0	0.140		
7	0	0.120	2	0.024
			0	0.017

ORIGINAL COPY

GENERAL

Detailed descriptions of methods of preparing lantern slides are given in textbooks. A very few references, however, give any quantitative data on the preparation of lantern-slide copy. The major problem in the preparation of legible lantern slides is in the preparation of the original copy. For this reason the recommended minimum requirements for legible lantern slides discussed here deal entirely with the *original lantern-slide copy*.

MINIMUM HEIGHT OF LETTERS

Arthur Knapp[5] presented a formula specifying the minimum width of lines

[4] "Engineering and Scientific Charts for Lantern Slides," prepared by the *American Society of Mechanical Engineers*, Sub-committee No. 4 on Engineering and Scientific Graphs, 1932.

[5] Arthur Knapp, "Technical Papers and Their Presentation," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 1 (January, 1928), pp. 77–83.

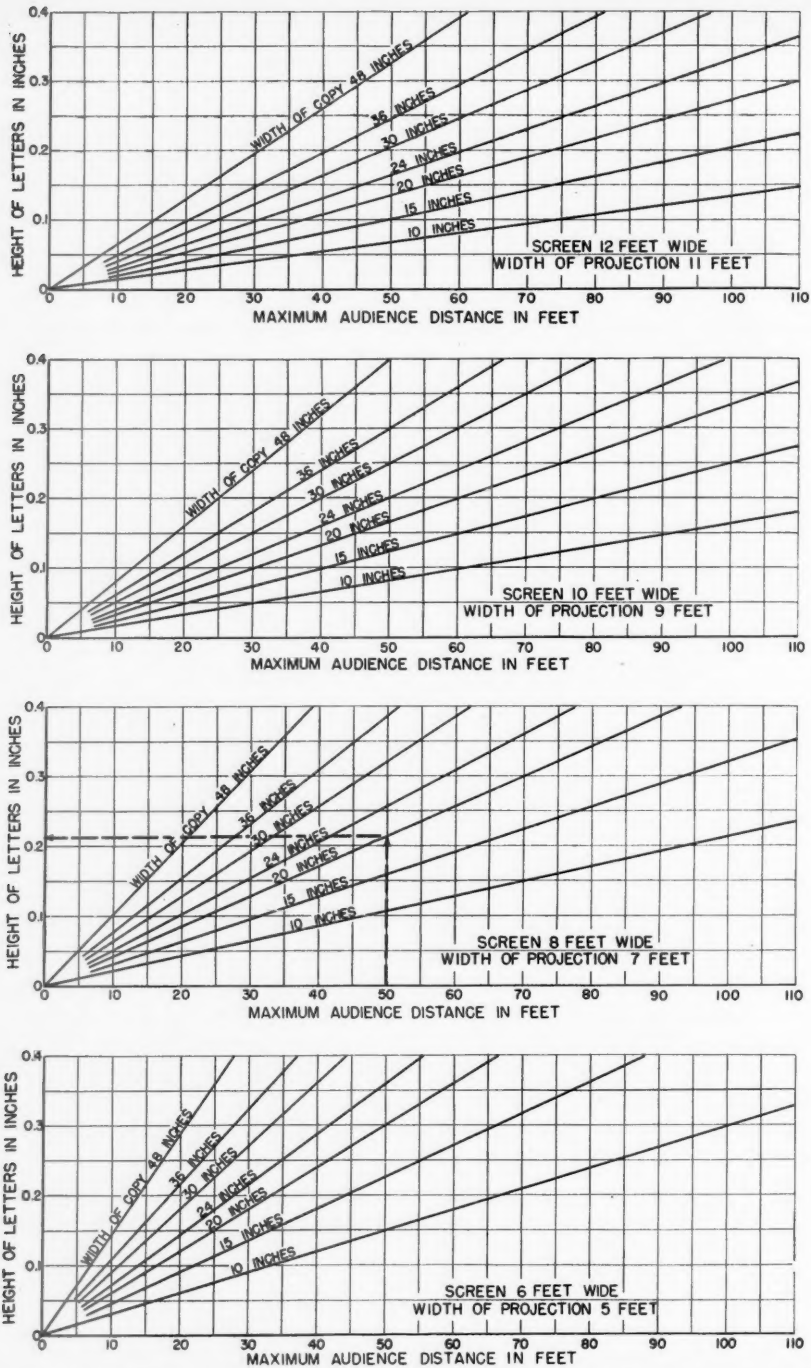


FIG. 2.—Graphic representation of minimum height of letters necessary for legibility, for given audience distance, given size of original copy, and for various projection screen widths.

on original lantern-slide copy that is necessary to insure legibility when the slide is projected on a screen. This formula took into consideration the following three controlling factors governing the legibility of lantern slides: (1) maximum size of lecture room, or maximum audience distance, (2) size or width of original lantern-slide copy, and (3) size or width of screen on which lantern slide is to be projected.

He discussed the minimum line to be used in forming letters and also the height of letters. The following formula for the minimum height of letters was modified from Knapp's original formula and discussion.

$$h = 0.0015 \frac{Ac}{P} \qquad (1)$$

h = Height of letters in inches
A = Maximum audience distance in feet
c = Width of original copy in inches
P = Width of projection onto a screen, in feet. (This is usually 80 percent of the width of screen)

When the height of the copy is more than 0.8 of the width, then $c = 1.25 \times$ height of copy, and not width of copy. (See appendix for a proof of this formula.)

Thus, on the assumption that the maximum audience distance is 50 feet, that the width of the original copy is 20 inches (multiple of standard page size, leaving margin), and that the width of projection is 7 feet (with an 8-foot screen), the minimum height of letters should be 0.21 inch (equivalent to Leroy and Wrico template No. 200).

The charts illustrated in Figure 2 are based on the foregoing formula (1), and afford a rapid means of determining graphically the desired minimum-height information. They can be used instead of the formula for most work. The charts include data for various projection-screen widths. Values for intermediate data may be interpolated from the charts.

In case the size of the room and the size of the screen are not known in advance when the lantern-slide material is being drafted, the values for a 50-foot maximum audience distance and an 8-foot screen may be used. These values will provide legible projection for the usual smaller lecture rooms. Large auditoriums will require still larger values.

Any draftsman, in preparing lantern-slide copy, can use the foregoing charts for the *minimum* size of letters and use larger letters for titles, main headings, *et cetera. Any lettering smaller than the foregoing values will not be legible when projected on a screen, under the given set of conditions.*

CURVES[6]

The curve is the most important element of a chart and should have the heaviest weight (thickness) of line to differentiate it sharply from the background.

Ordinarily, not more than three curves should be shown on the same chart. This limitation does not apply, however, to "families" of curves which are similar in shape and are well separated.

[6] Modified from "Engineering and Scientific Charts for Lantern Slides," *op. cit.*

If the curve represents a series of observations, the observed points should be shown, provided that they give additional essential information about the character of the data or about the reliability of the curve. Observed points should preferably be represented by circles or other closed symbols rather than by crosses. For such symbols, a minimum width of line should be used.

GRID RULINGS[7]

Grid rulings on a graph or chart should be limited in number to those necessary to guide the eye for an approximate reading. Closely spaced grid rulings such as appear on cross-section paper are, of course, appropriate for computation charts. In lantern-slide copy, however, such closely spaced grid rulings are a definite hindrance to legibility on charts.

Grid rulings, including boundaries of the grid area but excluding reference lines, should have the lightest weight (thickness) of any lines on the chart.

Principal lines of reference, such as the zero line, should be made heavier than other rulings but lighter than the curves. Grid rulings should not run through any lettering on the chart or through circles representing observed points.

GEOLOGIC MAPS, CROSS SECTIONS, AND ELECTRIC LOGS

In making up maps, cross sections, and electric logs for lantern-slide reproduction it is of utmost importance to bear in mind the foregoing formula for the minimum height of letters. Charts and diagrams are usually made by using only two or three different sizes or heights of letters. Cross sections and maps, on the other hand, should contain a number of different sizes of letters for ease in reading. These letters should range in size *upward* from the specified minimum size.

By using large, thin letters together with large, thick letters, it is possible to have two different types of lettering that vary only slightly in size yet are quite distinctive. The use of slanting letters adds another type of lettering for the drawing. Contrast for legibility may thus be achieved by using the size lettering guide with thick or thin, vertical or slanting, letters.

The lithological lines and symbols on a cross section should be considerably thinner than the formational boundaries. Such lines should not cross any lettering on the drawing but should be broken at words. This practice tends toward a clearer map or section, and the result is more legible. Figure 3 is a cross section prepared especially for lantern-slide reproduction. The minimum size of letters is that recommended by the foregoing formula and was calculated for a maximum audience distance of 50 feet and a projection width of 7 feet. While the original cross section in the *Bulletin* of the American Association of Petroleum Geologists[8] is entirely satisfactory for study at a desk, it is necessary to redraft it for lantern-slide presentation.

The grid rulings on maps, cross sections, and electric logs should be the thinnest or finest lines on the drawing—they should be visible but not prominent.

[7] Modified from "Engineering and Scientific Charts for Lantern Slides," *op. cit.*

[8] Taken from: Mississippi Geological Society, "Possible Future Oil Provinces of Southeastern United States," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, No. 8 (August, 1941), Fig. 3.

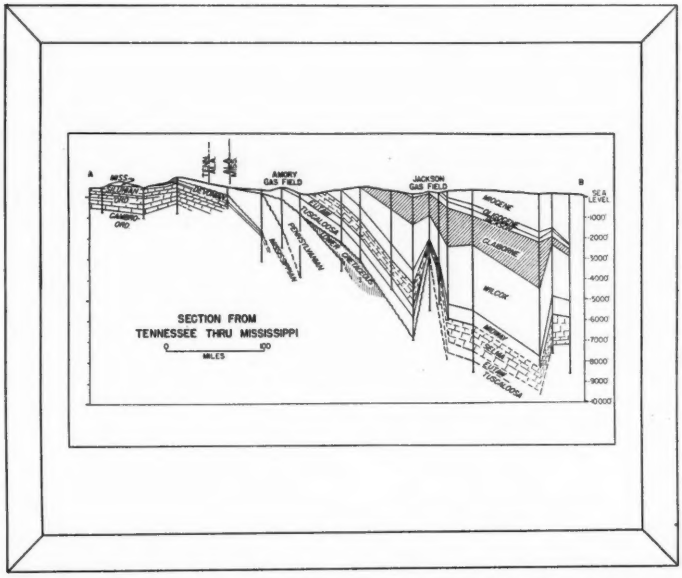


FIG. 3.—Generalized structure section from Tennessee through Mississippi. Redrafted from: Mississippi Geological Society, "Possible Future Oil Provinces of Southeastern United States," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, No. 8 (August, 1941), Fig. 3.

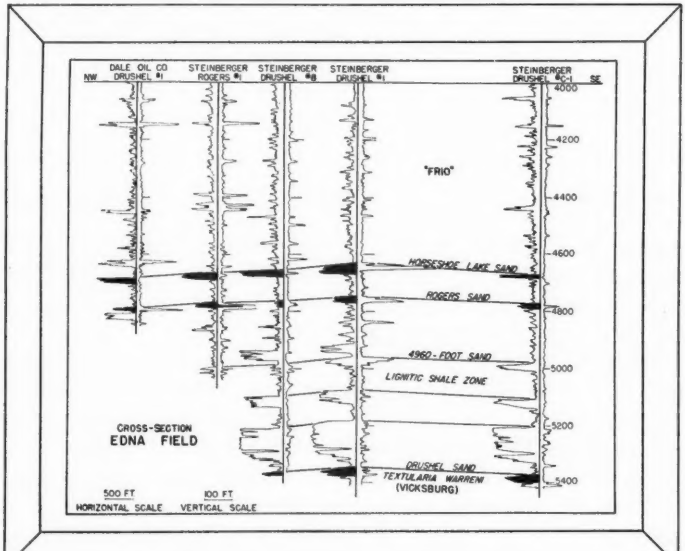


FIG. 4.—Electrical well-log correlations of Edna producing sands. Redrafted from: M. M. Kornfeld, and C. R. Steinberger, "Edna Gas Field, Jackson County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, No. 1 (January, 1941), Fig. 4.

The letters and lines should be spaced farther apart on lantern-slide copy to allow better legibility when projected. Figure 4 is a series of electric logs prepared for lantern-slide reproduction. As in Figure 3, the minimum size of letters is that recommended by the formula for a maximum audience distance of 50 feet and a projection width of 7 feet. The original drawing[9] is quite satisfactory for study at a desk, yet it should be redrafted for legible lantern-slide presentation.

Land and water areas on a map may be differentiated by shading or stippling. When the water areas are to be shaded, the legend and any titles may be boxed

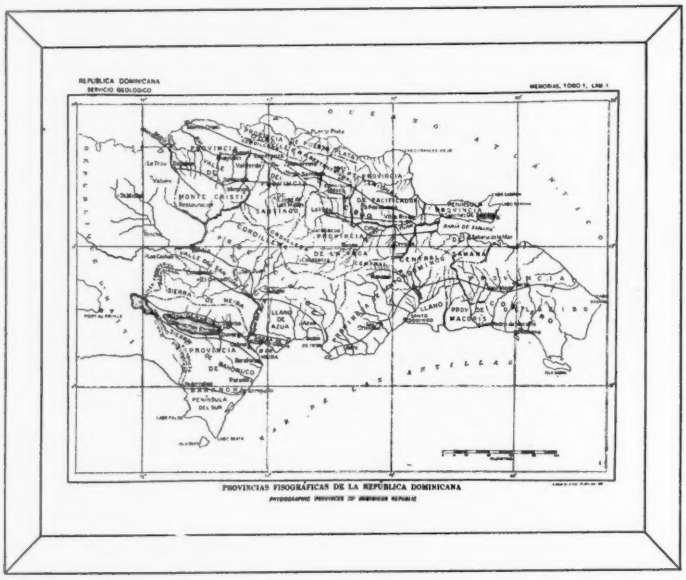


FIG. 5.—Physiographic map of Santo Domingo, illustrating poor lantern-slide copy.

off. Irregular stippling may be used to indicate the shoreline of land areas. This technique is especially effective when the water area is to be tinted on the lantern slide—the land area appears to "rise" from the water. In case the boundaries on the map coincide with a river, a single line may be used.

Figure 5 is a physiographic map of Santo Domingo that is satisfactory for examination and study at a desk. A legible lantern slide can not be made from it because: (1) there is too much detail on the map, (2) the minimum size of lettering is too small, (3) the scale caption is too small, and (4) there is not enough contrast in types of letters, and in the land and sea areas.

For these reasons a map of this type should be redrafted before being repro-

[9] Taken from: M. M. Kornfeld and C. R. Steinberger, "Edna Gas Field, Jackson County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, No. 1 (January, 1941), Fig. 4.

duced on a lantern slide. If the talk is to be about the physiographic provinces of Santo Domingo, for example, make these province lines stand out on the lantern-slide copy. In case drainage and culture are wanted, omit the physiographic provinces, put in the important rivers, and indicate important industrial centers.

Figure 6 is the same physiographic map of Santo Domingo, redrafted, with all the details omitted, yet with sufficient information for a clear presentation at a meeting. The minimum size of lettering on the map in Figure 6 conforms with the requirements of the formula for a 50-foot maximum audience distance and a

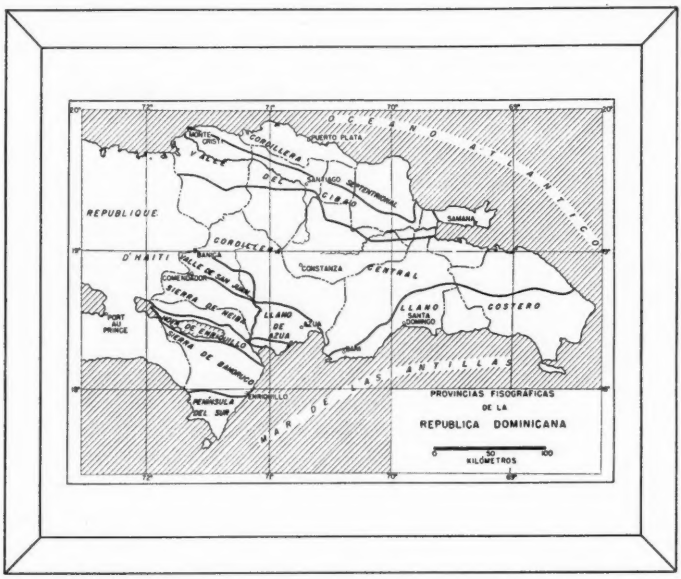


FIG. 6.—Same physiographic map of Santo Domingo as in Figure 5, redrafted for lantern-slide reproduction.

7-foot projection width; the physiographic boundaries are indicated by the heaviest lines on the map; the names of the physiographic provinces are lettered with the same size letter as is used for the names of the cities, but a wider pen and a slanting guide were used; the water area is indicated by shading for a maximum contrast; and the legend is boxed within the borders of the map.

Perhaps the most important point to consider in preparing maps, sections, and electric logs for lantern-slide reproduction is the amount of reduction that is involved. It is much better procedure to begin with a smaller original diagram for redrafting. Then the reduction to lantern-slide size is not so great. If one wishes to prepare a lantern slide of a large 3-foot map or cross section for a talk, the following procedure may be followed.

1. Photostat the large diagram down to a convenient but smaller size, maximum about 20 to 24 inches.

2. Trace the drawing on the reduced scale, omitting all the details and stressing only the significant points, formation boundaries, and such, that are necessary for the talk.

3. Take care to determine the minimum size of letters necessary for the 20 to 24-inch original copy size.

4. Bear in mind always that a lantern slide is "only an illustration. It presupposes an explanation by the speaker and usually can not be complete within itself."

TYPEWRITTEN COPY

The impression made by a typewriter appears, to the naked eye, to be a continuous ink impression. When magnified, however, the impression is found to be a series of irregular blotches made by the threads of the typewriter ribbon upon the irregular surface of the paper. It is for this reason that typewritten copy makes poor lantern-slide copy.

Where typewriter type must be used on a chart or on a statement, it may be found necessary to strike over each letter two or three times to produce a uniformly black impression. This is essential in order to obtain as nearly as possible the same density as the India ink on the chart.

If great speed is necessary and a typewriter must be used, the largest size *Pica* type is recommended. The letters of the typewriter should be carefully cleaned, and a hard paper and a new ribbon should be used. An electric typewriter with a carbon ribbon makes the best typewritten copy.

The size of the original chart, when a typewriter is used, should be reduced to about half of an $8\frac{1}{2}$-×11-inch page. The material should not be crowded on the chart—double spacing on the half page will give a legible slide, for average projection conditions.

A special typewriter with $\frac{1}{4}$-inch letters can be used in making charts for legible lantern-slide copy. The characters on the typewriter must be struck over several times to give a dense black line. This typewriter does not produce as neat results as do lettering guides, but for rush work the speed more than offsets the lack in appearance. To make the original, the chart is first laid out in pencil and the base and border lines drawn with India ink. The printed matter is typed last to avoid smudging of the typewriter impressions as much as possible.

JUDGING LANTERN-SLIDE COPY

Ordinarily, it is desirable to study a chart or a map to decide whether it will make a legible lantern slide. The approximate visibility of copy may be judged by placing it at a distance from the eye as determined from the following formula, modified from Knapp.[10]

[10] Arthur Knapp, *op. cit.*, p. 81.

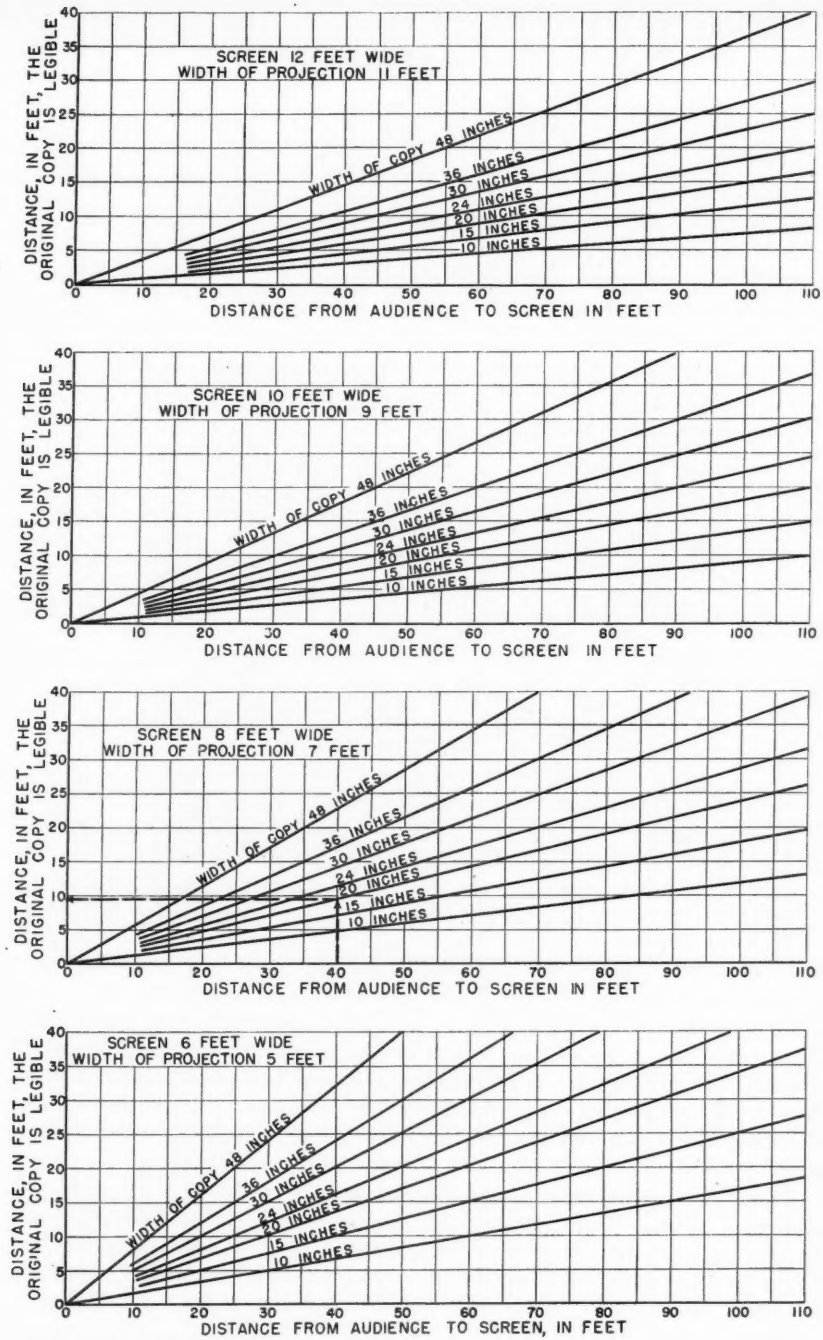


FIG. 7.—Graphic representation of distance from eye that copy must be readable in order to be legible when projected on screen. This takes into consideration maximum audience distance, width of original copy, and width of projection.

$$e=\frac{Ac}{12P}$$

e = Feet from eye to copy
A = Maximum audience distance in feet
c = Width of copy in inches
P = Width of projection upon the screen, in feet
When height of copy is more than 0.8 of the width, then $c=1.25\times$height and not width of copy.

For a maximum audience distance of 40 feet, width of copy 20 inches, and width of projection 7 feet, the lettering on the copy must be legible at a distance of 9.5 feet in order to be legible when projected on a screen. Figure 7 is a graphic

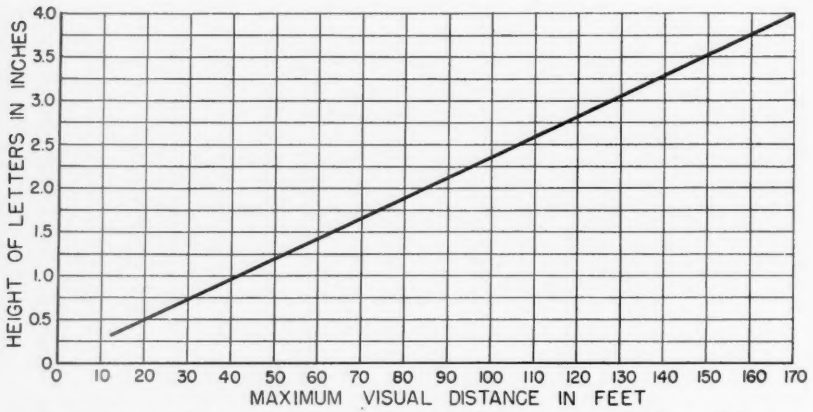


FIG. 8.—Diagram to demonstrate size of letters visible at given audience distances. Values have been increased by one-third to allow for diffusion of image on projection and for smoke and haze in lecture room.

representation of the distance from the eye the copy must be readable in order to be legible when projected on the screen. These curves give values for any audience distance, with a given width of original copy for a given projection. They also afford a rapid means of determining graphically the legibility of lantern-slide copy for given conditions of projection. The figure can be used instead of the formula for most work. Data for various projection screen widths are included, and values for intermediate data may be interpolated from the data given.

Figure 8 is a diagram prepared to demonstrate the size of letters that are visible for normal eyesight at given audience distances. This diagram has been prepared from a study of ophthalmological charts, tests with a large number of people, and by taking into consideration the conditions under which standard projectors are used. It calls for approximately one-third larger letters than the

regular optical charts published by the American Optical Company. This increase in size makes allowance for considerable diffusion upon projection and for the smoke and haze that are always found in lecture rooms.

NEGATIVE LANTERN SLIDES

Visibility is a function of the brightness contrast and the resolving power of the eye. Lantern slides are usually made as "positives," that is, they have black lines on a transparent background. The amount of light reflected from the screen

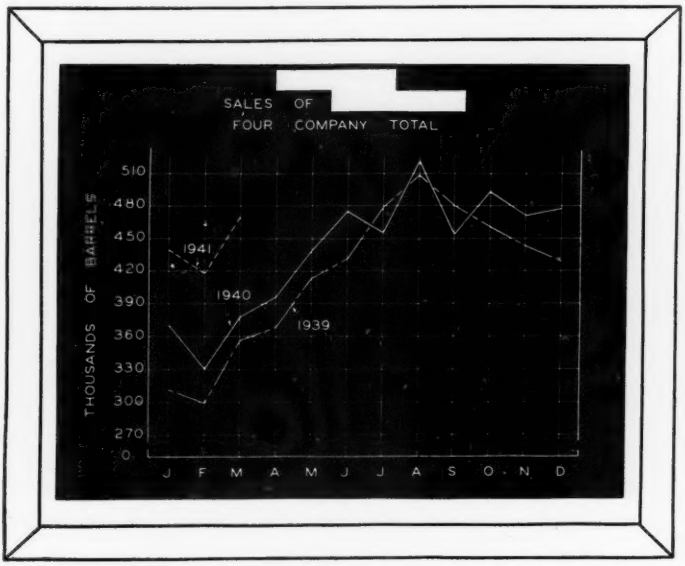


FIG. 9.—Line chart prepared for negative lantern-slide presentation. Lines may be hand-colored.

generally causes a glare, with the result that the retina opening of the eye is contracted, and visibility is thereby reduced.

Slides can be made with white lines on a black or reducing background, or as "negatives." This procedure cuts down the amount of reflected light without reducing the brightness contrast, and the visibility is better for the same thickness of line. Dark background or negative slides are more visible and are less tiring to the eye.

Negative slides tend to heat on projection since they absorb all the light and heat from the bulb. For this reason they are not recommended for general use where the projection is to be held for a considerable period of time, as in the discussion of technical details and trends.

Figure 9 illustrates a line chart prepared for negative lantern-slide presentation. The white lines of the chart on a dark background make it possible to have the lines hand-colored. The black background with white letters and colored lines is very effective and is highly legible.

Figure 10 is a bar chart prepared for a negative slide. The bars on the original are black but show white when photographed. The bars are colored by hand.

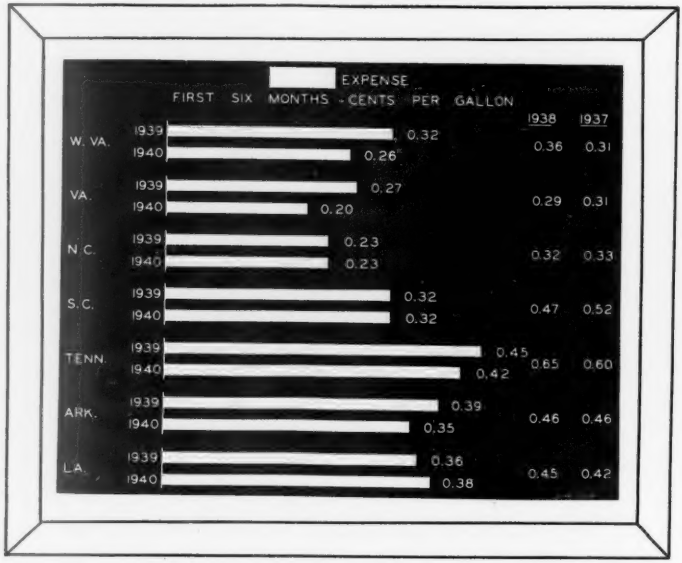


FIG. 10.—Bar chart prepared for negative lantern-slide presentation. Bars may be hand-colored.

The quickest way to apply bars to the original on this type of chart is with black scotch tape.

APPENDIX

The formula for the minimum height of letters $h = 0.0015 \frac{Ac}{P}$, was taken from Arthur Knapp's article[11] and no proof was given. D. C. Skeels, of the Standard Oil Development Company, New York, has suggested the following proof for this formula.

The original lantern-slide copy is reduced photographically to lantern-slide size and is then projected onto a screen of a given size. Thus in Figure 11, the size of the original lantern-slide copy falls between the size of the lantern slide and the size of the projected image.

[11] Arthur Knapp, *op. cit.*

According to ophthalmological charts prepared by the American Optical Company, New York, letters 1.75 inches high are legible to the normal eye at a distance of 100 feet (1,200 inches). The ratio of height to distance is $\frac{1.75}{1,200}$, or 0.0015 (approximately).

Therefore, since h' is the height of the sm allest legible letter on the screen and A is the limiting distance of visibility (as well as maximum audience distance) the

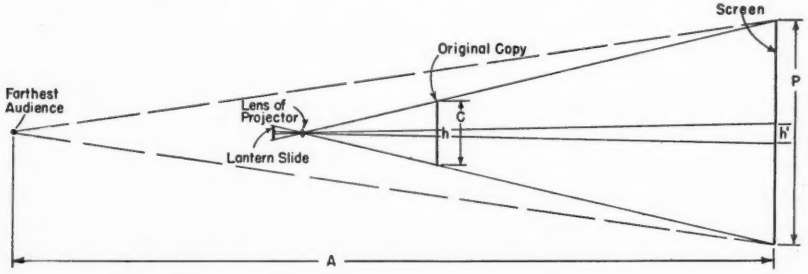


FIG. 11.—Diagram to show relationship between size of original copy, width of projection, and size of actual lantern-slide.

h = height of letters on original copy, in inches.
h' = height of projected letters on screen, in feet.
A = maximum audience distance, in feet.
c = width of original copy, in inches.
P = width of projection, in feet.

ratio of these two values must be at least 0.0015 in order for the letter to be legible.

$$\frac{h'}{A} = 0.0015$$

$$h' = 0.0015\ A.$$

From the geometry of the projection,

$$\frac{h}{h'} = \frac{c}{P} \text{ (Fig. 11)}$$

$$h = \frac{c \times h'}{P}$$

substituting $h' = 0.0015\ A$, the value becomes

$$h = 0.0015\ \frac{Ac}{P}.$$

The formula takes into consideration the three variables that control the minimum requirements for the legibility of lantern slides, namely, the maximum audience distance, the width of the original copy, and the width of the projection onto the screen.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 26, NO. 10 (OCTOBER, 1942), PP. 1672–1673

GEOLOGICAL NOTES

LATE PALEOZOIC AGE OF MOREHOUSE FORMATION OF NORTHEASTERN LOUISIANA[1]

RALPH W. IMLAY AND J. S. WILLIAMS[2]
Washington, D. C.

The Morehouse formation was defined[3] for 1,190 feet, as dark, silty shale and thin siltstone penetrated at depths from 9,285 to 10,475 feet in the Union Producing Company's Tensas Delta well No. A-1, Sec. 8, T. 22 N., R. 4 E., Morehouse Parish, Louisiana. The shale and siltstone are carbonaceous, siliceous, or finely micaceous, or less commonly calcareous. Some gray, sandy shales, sandy limestones, and red shales are included. The formation underlies the Eagle Mills salt, anhydrite, and redbeds with apparent conformity and gradational relationship. It was tentatively assigned to the Jurassic[4] on the basis of a sponge that appeared to be more similar to sponges of middle Mesozoic age than to sponges of Paleozoic age.

During April, 1942, the Union Producing Company granted Imlay the privilege of examining hundreds of pounds of cores of the Morehouse formation and of obtaining thereby about 50 external and internal molds of pelecypods and gastropods. As preliminary study of these fossils showed that they were upper Paleozoic in age, they were given to Williams for study and age determination. He found that the state of preservation of the pelecypods did not allow positive identification, but that all of them resembled genera commonly found in certain Pennsylvanian and Permian faunas. The gastropods, fortunately, belong to a bellerophontid genus, commonly identified with *Patellostium*, that has rather distinctive ornamentation. This genus, or forms commonly placed in it, ranges from Devonian to Permian. The ornamentation of the species in the Morehouse formation greatly resembles that of *P. montfortianum* Norwood and Pratten, recently made the genotype of *Cymatospira*,[5] but the specimens in hand are not complete enough for definite reference. The distinctive gastropod and the general resemblances of the pelecypods suggest that the Morehouse shale is late Paleozoic in age, probably not older than Pennsylvanian. A list of the fossils in the collection follows.

[1] Manuscript received, August 27, 1942. Published by permission of the director of the Geological Survey.

[2] Geologists, Geological Survey, United States Department of the Interior.

[3] Ralph W. Imlay, "Lower Cretaceous and Jurassic Formations of Southern Arkansas and Their Oil and Gas Possibilities," *Arkansas Geol. Survey Inf. Cir. 12* (1940), pp. 7, 8.

[4] Ralph W. Imlay, "Jurassic Fossils from Arkansas, Louisiana, and Eastern Texas," *Jour. Paleon.*, Vol. 15, No. 3 (1941), pp. 261, 262.

[5] J. Brookes Knight, "Four New Genera of Paleozoic Gastropoda," *Jour. Paleon.*, Vol. 16 (1942), p. 487.

FOSSILS IN MOREHOUSE FORMATION

	Depth in feet
Patellostium sp.	9,303
Sponge?	9,304–05
Patellostium sp.	9,308
Dentalium? sp.	9,313
Sphenotus aff. *S. vulgaris* Girty	9,858–59
Astartella? sp.	9,859–60
Sphenotus aff. *S. vulgaris* Girty	10,233–53
Astartella? sp.	10,233–53
Aviculipinna sp.	10,233–53
Pleurophorella? sp.	10,233–53
Nucula sp.	10,233–53
Cypricardinia? sp.	10,233–53
Schizodus? sp.	10,233–53
Patellostium sp.	10,233–53

The occurrence of a fairly thick section of late Paleozoic rocks directly beneath Upper Jurassic rocks on the Monroe uplift of northeastern Louisiana furnishes information concerning the extent of the late Paleozoic seas, the southern margin of the Ouachita geosyncline, and the beginning of Mesozoic sedimentation. Lithologically, the Morehouse formation is identical with the steeply dipping Carboniferous shales penetrated by drilling in central Mississippi, according to Tom McGlothlin,[6] but differs in having no apparent dip. This lack might be explained by the location of the well on the axis of a fold, or by the occurrence of the beds on the site of a stable mass that resisted folding. The geographic position of the Morehouse formation indicates that it was formed in the southern part of the Ouachita geosyncline and was probably affected by the intense folding of that structure in late Paleozoic time. The superposition of the Eagle Mills formation directly on the Morehouse formation dates approximately the beginning of Jurassic sedimentation in northeastern Louisiana but does not prove that Mesozoic rocks older than Eagle Mills may not occur elsewhere in the Gulf region. Determination of the late Paleozoic age of the Morehouse formation is of economic importance, as the chances of finding oil below the Upper Jurassic sequence in northeastern Louisiana are much less favorable than if the underlying beds were Mesozoic in age.

CORRECTION

STRATIGRAPHY OF NORTH DAKOTA

In the discussion, "Stratigraphy of North Dakota," by O. A. Seager *et al.*, in the August *Bulletin*, page 1423, paragraph 4, line 4, "Grant County, North Dakota" should read Grant County, *South* Dakota.

[6] Personal communication, Gulf Refining Company, Jackson, Mississippi.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 26, NO. 10 (OCTOBER, 1942), P. 1674

REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library, and available, for loan, to members and associates.

RECENT PUBLICATIONS

ARKANSAS

*"Pitkin Limestone of Northern Arkansas," by William H. Easton. *Arkansas Geol. Survey Bull. 8* (Little Rock, 1942). 115 pp., 10 figs., 12 pls. of fossils. Paper cover. 6×9 inches. Price, $0.60.

CALIFORNIA

*"Oil and Gas Fields of San Joaquin Valley and Northern California," by Paul J. Howard. *California Oil World*, Vol. 35, No. 16 (Los Angeles, August 27, 1942), pp. 5–13, 21–31.

*"Oil Fields of Southern California," by Vernon L. King. *Ibid.*, pp. 33–57.

ENGLAND

*"Some New Sections and Fossils from the Folkstone Beds of the Farnham District," by C. W. and E. V. Wright. *Proc. Geol. Assoc.*, Vol. 53, Pt. 2 (London, July 13, 1942), pp. 86–87.

*"The Eocene Succession at Afton Brickyard, I. O. W.," by Dennis Curry. *Ibid.*, pp. 88–101; 1 pl.

GENERAL

*"Time Relations in Ocean Sediments," by C. S. Piggot and Wm. D. Urry. *Bull. Geol. Soc. America*, Vol. 53, No. 8 (New York, August 1, 1942), pp. 1187–1210; 4 figs.

*"Mississippi Delta—a Study in Isostasy," by Andrew C. Lawson. *Ibid.*, pp. 1231–54; 2 figs.

**Tulsa Geological Society Digest, 1941–1942* (August, 1942). 108 pp. Abstracts of papers presented before the Society from October, 1941, to June, 1942. Copies may be obtained from John S. Redfield, business manager, Stanolind Oil and Gas Company, Tulsa, Oklahoma. Price, $0.50.

"Methods for Determining Permeability of Water-Bearing Materials, with Special Reference to Discharging-Well Methods," by L. K. Wenzell. Contains a section on direct laboratory methods and bibliography on permeability and laminar flow, by V. C. Fishel. *U. S. Geol. Survey Water-Supply Paper 887* (May, 1942). 192 pp., 6 pls., 17 figs. Supt. Documents, Govt. Printing Office, Washington, D. C. Price, $0.60.

TEXAS

Field and Laboratory, Vol. 10, No. 2 (Southern Methodist University, Dallas, Texas, July, 1942). Contains 2 articles on geology: (1) "Landslide Blocks along Margin of Diablo Plateau," by R. D. Trace; (2) "Dinosaur Tracks near Comanche, Texas," by C. C. Albritton.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 26, NO. 10 (OCTOBER, 1942), PP. 1675-1691

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

Finn Eyolf Bronner, Los Angeles, Calif.
Drexler Dana, John W. Mathews, C. W. Tomlinson

Richard Lane Denham, New Orleans, La.
J. Ben Carsey, Dean F. Metts, Morgan J. Davis

Theodore Phelps Ellsworth, Bakersfield, Calif.
Rollin Eckis, Thomas J. Fitzgerald, Mason L. Hill

Willard Alexander Findlay, San Francisco, Calif.
J. O. Nomland, C. St. J. Bremner, John P. Buwalda

Roe Austin Gray, Los Angeles, Calif.
Everett C. Edwards, C. M. Wagner, Elmer L. De Maris

Allen Roys Ostrander, Enid, Okla.
W. H. Twenhofel, Ernest Rice Smith, H. L. Koch

Harold Raymond Prescott, Ponca City, Okla.
Everett C. Parker, Stuart K. Clark, Glenn C. Clark

Joe Henry Watkins, Charleston, S. C.
John C. McCampbell, J. W. Huddle, H. W. Straley, III

James Sharples Wise, Okmulgee, Okla.
G. H. Westby, T. E. Weirich, Constance J. Eirich

FOR ASSOCIATE MEMBERSHIP

Raymond J. Berryman, Bakersfield, Calif.
R. H. Beckwith, Horace D. Thomas, Arthur F. Peterson

Harold Slentz Edwards, Fort Worth, Tex.
F. H. Schouten, William J. Nolte, Raymond C. Moore

FOR TRANSFER TO ACTIVE MEMBERSHIP

John Sublett Herold, c/o Postmaster, New York, N. Y.
Robert I. Dickey, Robert E. King, John M. Hills

ASSOCIATION COMMITTEES

EXECUTIVE COMMITTEE

Fritz L. Aurin, *chairman*, Southland Royalty Company, Fort Worth, Texas
Edmond O. Markham, *secretary*, Carter Oil Company, Tulsa, Oklahoma
Edgar W. Owen, San Antonio, Texas
Paul Weaver, Gulf Oil Corporation, Houston, Texas
W. A. Ver Wiebe, University of Wichita, Wichita, Kansas

REPRESENTATIVE ON DIVISION OF GEOLOGY AND GEOGRAPHY NATIONAL RESEARCH COUNCIL: A. I. Levorsen (1943)

REPRESENTATIVES ON COMMISSION ON CLASSIFICATION AND NOMENCLATURE OF ROCK UNITS

Benjamin F. Hake (1943) Monroe G. Cheney (1944) John G. Bartram (1945)

FINANCE COMMITTEE

E. DeGolyer (1943) Ira H. Cram (1944) Joseph E. Pogue (1945)

TRUSTEES OF REVOLVING PUBLICATION FUND

Frank A. Morgan (1943) Glenn C. Clark (1944) W. B. Wilson (1945)

TRUSTEES OF RESEARCH FUND

L. Murray Neumann (1943) Olin G. Bell (1944) Walter R. Berger (1945)

BUSINESS COMMITTEE

D. Perry Olcott (1943), *chairman*, Humble O. & R. Co., Box 2180, Houston, Texas
Roy M. Barnes (1943), *vice-chairman*, Continental Oil Co., Los Angeles, California

Karl Arleth (1944)
Fritz L. Aurin (1944)
W. C. Bean (1944)
R. C. Bowles (1944)
Leslie Bowling (1944)
C. C. Clark (1943)
Herschel L. Driver (1943)
Fred B. Ely (1943)
L. L. Foley (1943)
John L. Garlough (1943)
Darsie A. Green (1943)
Albert Gregersen (1943)
Dilworth S. Hager (1944)
Marcus A. Hanna (1943)
T. C. Hiestand (1944)
Urban B. Hughes (1943)
Archie R. Kautz (1944)
W. D. Kleinpell (1943)
Robert N. Kolm (1944)
Max L. Krueger (1944)
C. S. Lavington (1943)
Theo. A. Link (1943)
J. R. Lockett (1943)
D. A. McGee (1943)
Edmond O. Markham (1943)
Phil F. Martyn (1943)
Dean F. Metts (1943)
Frank B. Notestein (1943)
Edgar W. Owen (1943)
George W. Pirtle (1943)
Louis Roark (1943)
Henryk B. Stenzel (1943)
L. W. Stephenson (1944)
L. W. Storm (1943)
C. D. Vertrees (1943)
W. A. Ver Wiebe (1943)
Paul Weaver (1943)
Neil H. Wills (1943)
L. E. Workman (1943)
C. E. Yager (1943)

COMMITTEE FOR PUBLICATION

J. V. Howell (1945), *chairman*, 912 Philtower Building, Tulsa, Oklahoma

1943	1944	1945
B. W. Blanpied	Alfred H. Bell	Joseph L. Borden
H. E. Christensen	John W. Inkster	Kendall E. Born
Max L. Krueger	Robert N. Kolm	Clifton L. Corbett
Jed B. Maebius	Hans G. Kugler	Lynn K. Lee
Karl A. Mygdal	Jerry B. Newby	E. Russell Lloyd
O. A. Seager	Paul H. Price	H. E. Minor
L. W. Storm	J. D. Thompson	
H. V. Tygrett	Henry N. Toler	

RESEARCH COMMITTEE

A. I. LEVORSEN (1945), *chairman*, 221 Woodward Boulevard, Tulsa, Oklahoma
M. G. CHENEY (1945), *vice-chairman*, Coleman, Texas

1943	1944	1945
ROLAND F. BEERS	BEN B. COX	N. WOOD BASS
LESLIE C. CASE	GEORGE C. GESTER	RONALD K. DEFORD
HOLLIS D. HEDBERG	W. S. W. KEW	M. G. EDWARDS
THOMAS C. HIESTAND	D. PERRY OLCOTT	WINTHROP P. HAYNES
JOHN M. HILLS	WENDELL P. RAND	PHILIP B. KING
WILLIAM C. KRUMBEIN	F. W. ROLSHAUSEN	PAUL H. PRICE
F. B. PLUMMER	F. M. VAN TUYL	
W. H. TWENHOFEL	PAUL WEAVER	
THERON WASSON		

GEOLOGIC NAMES AND CORRELATIONS COMMITTEE

JOHN G. BARTRAM (1945), *chairman*, Stanolind Oil and Gas Company, Tulsa, Oklahoma

1943	1944	1945
ANTHONY FOLGER	MONROE G. CHENEY	ROBERT I. DICKEY
BENJAMIN F. HAKE	ROBERT H. DOTT	GENTRY KIDD
ROBERT M. KLEINPELL	WAYNE V. JONES	HUGH D. MISER
NORMAN D. NEWELL	W. ARMSTRONG PRICE	RAYMOND C. MOORE
CHARLES W. TOMLINSON	HORACE D. THOMAS	
	WARREN B. WEEKS	

SUB-COMMITTEE ON CARBONIFEROUS

M. G. CHENEY (1945), *chairman*, Coleman, Texas

1943	1944	1945
BENJAMIN F. HAKE	ROBERT H. DOTT	RAYMOND C. MOORE
NORMAN D. NEWELL	HORACE D. THOMAS	
CHARLES W. TOMLINSON		

SUB-COMMITTEE ON TERTIARY

W. ARMSTRONG PRICE (1944), *chairman*, Box 1860, Corpus Christi, Texas

THOMAS L. BAILEY	WAYNE V. JONES	WATSON H. MONROE
MARCUS A. HANNA	GENTRY KIDD	E. A. MURCHISON, JR.
HENRY V. HOWE	TOM MCGLOTHLIN	WARREN B. WEEKS

COMMITTEE ON APPLICATIONS OF GEOLOGY

PAUL WEAVER (1944), *chairman*, Gulf Oil Corporation, Houston, Texas
HENRY C. CORTES (1944), *vice-chairman, geophysics*, Dallas, Texas
CAREY CRONEIS (1943), *vice-chairman, paleontology*, Chicago, Illinois

1943	1944	1945
R. M. BARNES	GEORGE S. BUCHANAN	
CARROLL E. DOBBIN	WESLEY G. GISH	
H. S. MCQUEEN	KENNETH K. LANDES	
B. B. WEATHERBY		

SPECIAL COMMITTEES

COMMITTEE ON COLLEGE CURRICULA IN PETROLEUM GEOLOGY

FREDERIC H. LAHEE, *chairman*, Sun Oil Company, Dallas, Texas

L. T. BARROW	WINTHROP P. HAYNES	JOHN D. MARR
WALTER R. BERGER	K. K. LANDES	E. K. SOPER
HAL P. BYBEE	HENRY A. LEY	W. T. THOM, JR.
IRA H. CRAM	JOHN T. LONSDALE	

NATIONAL SERVICE COMMITTEE

FRITZ L. AURIN, *temporary chairman*, Southland Royalty Company, Fort Worth, Texas
A. RODGER DENISON, *vice-chairman*, Amerada Petroleum Corporation, Tulsa, Oklahoma

A. E. BRAINERD	EUGENE HOLMAN	GEORGE D. PUTNAM
IRA H. CRAM	ROBERT F. IMBT	CARLETON D. SPEED, JR.
RONALD K. DEFORD	J. R. LOCKETT	WILLIAM H. SPICE, JR.
M. GORDON GULLEY	FRANK A. MORGAN	B. B. WEATHERBY
K. C. HEALD	EDGAR W. OWEN	W. E. WRATHER

DISTINGUISHED LECTURE COMMITTEE

JOHN L. FERGUSON, *chairman*, Amerada Petroleum Corporation, Tulsa, Oklahoma

LON D. CARTWRIGHT, JR.	DARSIE A. GREEN	CHARLES E. YAGER
	JOHN W. INKSTER	

MEMBERS OF THE A.A.P.G. IN MILITARY AND GOVERNMENT SERVICE

F. L. AURIN[1]
Fort Worth, Texas

It will be of interest to the membership of the A.A.P.G. to see the most complete list that it is possible to make at this time, of the members who are now in the Armed Forces of the United States and Allied Nations. This list is not complete by any means, as many who have entered the service have not reported that fact to Headquarters. We are dependent on the individuals and affiliated geological societies and other sources for furnishing us with this desired information. Most of the geological societies have been very coöperative, but some individuals have omitted sending in the desired information, although this has been called to their attention many times. Even though you may not think about the importance of this, in our opinion it may be of considerable future value to these men and may also be desirable information to have when requested by or presented to the Armed Forces. With some of the programs in mind that the National Service Committee is working on, every attempt is being made to keep this information up to date. Furthermore, this entails much work on the part of the National Service Committee and the Headquarters office.

It may be of interest to note the approximate distribution of the membership in the several branches of the Armed Forces, as follows:

Army Air Corps	96
U. S. Navy (including Aviation)	58
Infantry	38
Field Artillery (including Anti-Tank Bn.)	28
Corps of Engineers	22
Armored Force	12
Coast Artillery and Guard	14
Army Ordnance	8
Signal Corps	6
Miscellaneous	13
Total	295

This record shows only 295 in the service; however, in our opinion, there are at least a sufficient number of unreported ones to make a conservative estimate of 335 members in the service. Almost every day a substantial number of notices is coming into Headquarters. Most of those reporting are going into the Army Air Corps. The predominant reason for this is that the geologist, and especially the petroleum geologist, can use his training and experience to good advantage in this branch of service which has invited his services. In fact, in every branch of the service including the Infantry, Field Artillery, Armored Force, Coast Artillery, and others, but more especially the Corps of Engineers, his geological engineering, and other possible services as a geologist can be utilized most effectively to render valuable advice and assistance.

Our readers are urged to look over the list carefully and send in as promptly as possible any additions or corrections so that the list may be made as accurate and complete as possible and kept up to date.

It may also be of interest to realize that a great many of our members are doing other kinds of work toward the war effort. Many of them are working with the United States Geological Survey, the Bureau of Economic Warfare, and the Bureau of Mines in the search for strategic minerals. This is one of the most important phases of geological

[1] Chairman, A.A.P.G. National Service Committee.

work carried on by the Government agencies and such work is not only in active operation but is also expanding very rapidly.

In addition to the work on strategic minerals, many of our members are doing geological engineering work such as investigating water supplies and advisory services in construction work in connection with military and Defense projects.

In the Office of Petroleum Coördinator for War, extremely important work is being done and you will note that our membership is well represented in many of the important positions of that organization.

We are certain that this list of members of the A.A.P.G. now serving in the employ of the United States and Allied Countries in a civilian capacity is not complete. Again our readers are urged to send in any information they have regarding members omitted from the list or any corrections on those included in the list.

MEMBERS OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS SERVING IN THE ARMED FORCES OF THE UNITED STATES AND ALLIED COUNTRIES

Name	*Home Address*	*Rank*	*Branch of Service*
Achning, Walter J.	Rt. 1, Box 51 Colorado Springs, Colo.	Capt.	Army Air Corps
Adams, Clyde B.	93 Paul Revere Rd. Needham Heights, Mass.		U.S. Army
Akers, Wilburn H.	1029 S.W. Twenty-eighth St. Oklahoma City, Okla.	Lt.	U.S. Army
Allen, William H.	Box 1509 Midland, Tex.	Lt.	Cavalry, U.S. Army
Allen, William Odis, Jr.	1331 E. Twenty-sixth St. Tulsa, Okla.	Lt.	Tank Destroyer Bn.
Anderson, James B.	415 W. Lomita Ave. Glendale, Calif.	Pvt.	Field Artillery
Anderson, Kenneth C.	3701 Benton Blvd. Kansas City, Mo.	Pvt.	Medical Corps
Anderson, Oscar S., Jr.	Big Four Petr. Co. Box A, Oilton, Okla.		Field Artillery
Anderson, Thomas I.	2250 Parnell Ave. W. Los Angeles, Calif.	Corp.	Coast Artillery
Arick, M. B.	Midland, Tex.	Lt.	Army Air Corps
Arnold, H. H.	131 Seventh Ave. Clarion, Pa.	Lt.	Army Air Corps
Austin, Robert B.	631 W. Fifty-ninth St. Kansas City, Mo.		Corps of Engineers
Bachman, Ford F.	Hq. Co., III Army Corps A.P.O. 303 Fort McPherson, Ga.	Lt.	U.S. Army
Baldwin, E. B.	Esperson Bldg. Houston, Tex.	Lt.	U.S. Navy
Barnes, Sydney U.	5900 Carlton Way Hollywood, Calif.	Lt.	Field Artillery
Bartle, Glenn G.	5604 Holmes St. Kansas City, Mo.	Lt.	U.S. Navy
Bartley, Jerald Howard	Box 2053 Glen Rose, Tex.	Ens.	U.S.N.R.
Bates, Charles C.	10912½ Wellworth Village Sta. Los Angeles, Calif.	Avn. Cadet	Army Air Corps
Batla, Thomas W.	Bellville, Tex.		U.S. Army
Baxter, John C.	Camp Stewart, Ga.	Lt.	Coast Artillery
Baysinger, Eugene M.	Box 210 Lake Charles, La.	Lt.	Corps of Engineers

Name	*Home Address*	*Rank*	*Branch of Service*
Beach, Hugh Hamilton	Geol. Survey, Victoria Museum Ottawa, Ont., Canada	Lt.	R.C. Air Force
Beatty, Robert M.	2002 Calumet Houston, Tex.	Ground Officer	Army Air Corps
Becker, Leroy Everett	437 Lincoln St., Princeton, Ill.		U.S. Army
Beckwith, R. H.	1421 Sheridan St. Laramie, Wyo.	Capt.	U.S.M.C.R.
Bell, Olin G.	5519 Jackson St. Houston, Tex.	Major	Army Air Corps
Bemis, Harold C.	1090 W. Beverly Blvd. Whittier, Calif.	Officer	U.S. Army
Bescher, Earl, Jr.	3803 B Speedway Ave. Austin, Tex.	Pvt.	Army Air Corps
Blair, Robert William	531 Marion St., Denver, Colo.	Lt.	Army Air Corps
Boling, Kenneth G.	306 S. Elliot St. Olney, Ill.		U.S. Army
Bonar, Robert E.	Box 532 Denton, Tex.	Pvt.	Army Air Corps
Borax, Eugene	2843 City Terrace Dr. Los Angeles, Calif.		Army Air Corps
Bradbury, Albert E.	Box 335, Evanston, Wyo.	Lt.	Army Air Corps
Breed, E. R., Jr.	U.S.S. Chevalier, c/o Postmaster New York, N.Y.	Lt.	U.S. Navy
Brown, J. Earle	807 Trinity Life Bldg. Fort Worth, Tex.	Maj.	Army Air Corps
Bryan, Carl L.	2405 Isabella Ave. Houston, Tex.	Lt.	U.S.N.R.
Buehner, John Hubert	515 S. Nineteenth St. Belleville, Ill.	Lt.	Army Air Corps
Burchard, Frederick L.	5929 Goodwin Ave., Dallas, Tex.	Lt.	Army Air Corps
Burt, Roy Allen	Transportation Dept. Huntsville Arsenal Huntsville, Ala.	Maj.	U.S. Army
Burke, James D.	404 Frank Ave. Lufkin, Tex.		U.S. Marine Corps
Bush, Robert Ewell	Btry. C-31 Bn., F.A.R.T.C. Fort Sill, Okla.	Lt.	Field Artillery
Campbell, John M.	Box 278, Laredo, Tex.	Lt.	U.S.N.R.
Campbell, William R.	418 Thelma Dr. San Antonio, Tex.	Lt.	U.S. Army
Cardwell, William Henry	506 Driscoll Bldg. Corpus Christi, Tex.	Avn. Cadet	U.S. Navy
Carter, G. R.	361st School Sqn. Bldg. 616 Lowrey Field, Denver, Colo.	Pvt.	Army Air Corps
Cartwright, Weldon E.	2521 Wabash Ave. Fort Worth, Tex.		U.S.N.R.
Chambers, Robert J.	Co. H, 385th Inf., 76th Div. Fort George G. Meade, Md.	Lt.	Infantry
Chappuis, Louis C.	437 S. Hill St. Los Angeles, Calif.	Capt.	Army Air Corps
Clarke, Robert L.	Box 1245 Midland, Tex.	Lt.	U.S.N.R.
Clarkson, W. G., Jr.	224 W. Ave. A San Angelo, Tex.		U.S. Coast Guard
Classen, Willard J.	R.F.D. Box 330-D Redwood City, Calif.	Capt.	Army Air Force
Clinkscales, Albert S.	904 Colcord Bldg. Oklahoma City, Okla.	Maj.	Army Air Corps
Cogen, William M.	1079 S. Ogden Dr. Los Angeles, Calif.	Lt.	Army Air Corps
Coil, Fay	Box 510 Midland, Tex.	Capt.	Field Artillery

Name	*Home Address*	*Rank*	*Branch of Service*
Coldwell, Charles H.	830 Milam Bldg. San Antonio, Tex.	Lt.	U.S.N. Air Corps
Conselman, Frank B.	Gulf Oil Corp., Wichita, Kans.	Maj.	Army Air Corps
Colton, Howard F.	937 Milam Bldg. San Antonio, Tex.	Lt.	Army Air Corps
Cooke, H. C.	407 W. Thirty-second St. Austin, Tex.		U.S.N.R.
Cooper, C. Harrison	A.P.O. 7 Camp Luis Obispo, Calif.	Capt.	Field Artillery
Corey, George S.	10th Photo (Rcn.) Sqn. Army Air Base Colorado Springs, Colo.	Lt.	Army Air Corps
Corning, Leavitt, Jr.	A.C.O.T.S. Miami Beach, Fla.	Lt.	Army Air Corps
Couser, C. W.	3916 N. Fifth St., Apt. 3 Arlington, Va.	Lt.	Army Air Corps
Cox, Robert T.	Atlantic Refg. Co. Midland, Tex.	Lt.	Coast Artillery
Cox, Wesley Philip	7705 Military Dr. Dallas, Tex.	Capt.	Field Artillery
Cuyler, Robert H.	Univ. of Texas, Austin, Tex.	Lt.	Army Air Corps
Dake, Laurence F.	1106 Main St., Rolla, Mo.	Pvt.	Army Air Corps
Dana, Drexler	Newton, Ill.	Maj.	Corps of Engineers
Daniel, E. J.	c/o Messrs. Grindlay & Co. Bombay, India	Lt.	H. M. Forces
Daubert, Charles A.	2102 W. Kings Highway San Antonio, Tex.	Capt.	Army Air Corps
Davies, Jack W.	Co. A, Reception Center Camp Wolters, Tex.	Pvt.	U.S. Army
Davis, Leon V.	806 Merrick St. Henryetta, Okla.	Lt.	Field Artillery
Day, James R.	Midland, Tex.	Lt.	Coast Guard
Decker, Willis M.	Goddard, Kans.	Avn. Cadet	U.S.N. Air Corps
DeGoes, Louis L.	4661 Pickford St. Los Angeles, Calif.	Lt.	Army Air Corps
Deputy, P. R.	1035 N. Edgefield Dallas, Tex.	Lt.	Army Air Corps
Dinsmoor, C. G.	423rd Coast Art. Bn. (Comp.) (AA), Btry. D A.P.O. 1004, c/o Postmaster New York, N.Y.	Lt.	Coast Artillery
Doell, Edward C.	42-3 F St., 11-C Camp Taft, Calif.		U.S. Army
Doshier, Achille W.	827 Carolina Amarillo, Tex.		Corps of Engineers
Dougherty, W. E.	402 N Pecos, Midland, Tex.		U.S. Army
Dunn, David A.	Box 202, Tech. Sta. Lubbock, Tex.	Lt.	Army Air Corps
Durgan, Herbert L.	Btry. C, 31st Bn., 6th Reg. F.A. Repl. Tng. Center Fort Sill, Okla.	Lt.	Field Artillery
Eaton, J. Edmund	2062 N. Sycamore Ave. Los Angeles, Calif.	Maj.	Army Air Corps
Egan, J. A.	Palace Bldg., Tulsa, Okla.	Capt.	U.S. Army
Elkins, Campbell H.	1803 Thirteenth St. Lubbock, Tex.	Lt.	Army Air Corps
Elliott, A. C.	Infantry Reserve Fort Benning, Ga.	Lt.	Infantry
Elliott, J. E.	430 W. Peachtree St. Atlanta, Ga.	Maj.	Chemical Warfare Div.
Ervin, Lynn D.	Box 70, R. 2 Glenwood Springs, Colo.	Lt.	U.S. Navy

Name	*Home Address*	*Rank*	*Branch of Service*
Esunas, Bernard Joseph	Turner Field Albany, Ga.	Lt.	Army Air Corps
Fanguy, Nolan A.	639 E. Park Ave. Houma, La.	Avn. Cadet	Army Air Corps
Ferebee, D. M.	317 S. Seventh St. Mount Vernon, Ill.		U.S. Navy
Ferguson, John I.	826th T.D. Bn. (H) E. Garrison Camp Roberts, Calif.		Field Artillery
Ferrell, Max E.	Mountain View, Mo.	Capt.	Infantry
Fisher, Dunbar A.	Box 1271 Corpus Christi, Tex.	Lt.	U.S. Navy
Fitts, L. E., Jr.	Sinclair Prairie Oil Co. Box 521 Tulsa, Okla.		U.S. Army
Foster, Alden W.	2247 Oliver Bldg. Pittsburgh, Pa.	Capt.	Army Air Corps
Fouts, J. M.	Box 591 Morgan City, La.		U.S. Army
Franklin, Donald Wilbert	302nd (C.A.) Bar. Bln. Bn. Camp Tyson, Tenn.	Lt.	Coast Artillery
Frederickson, Edward A.	1105 Rutledge St. Madison, Wis.	Lt.	Army Air Corps
Fryou, Joe A.	112th Obsn. Sqdn. Dover, Del.	Lt.	U.S. Army
Galbreath, Glenn	2808 S. Cincinnati Tulsa, Okla.	Sgt.	Observation Sqn.
Gardner, Frank J.	582nd Ordnance Co. (Am.) 2nd Army Depot Nashville, Tenn.	Lt.	U.S. Army
Garrett, J. B., Jr.	216 Branard St. Houston, Tex.	Lt.	Infantry
George, Robert Freeman	705 Union Natl. Bank Bldg. Wichita, Kans.	Lt.	Army Air Corps
Gibson, Donald T.	2008 Twenty-sixth St. Lubbock, Tex.	Ens.	U.S.N.R.
Girdler, Tom M., Jr.	Apt. 12, 12065 Edgewater Dr. Lakewood, Ohio	Lt.	U.S. Army
Gisburne, John R.	5 Eddie St., Quincy, Mass.	Ens.	U.S.N.R.
Golden, John M.	Post Hqrs., 1853rd Service Unit Camp Bowie, Tex.	Lt.	Corps of Engineers
Goldsmith, L. Jean	3120 Thirty-eighth St., N.W. Washington, D.C.		U.S. Navy
Goodman, Herbert Maynard	Coin, Ia.		Tank Destroyer Bn.
Goodrich, Paul K.	Hq. III Army Corps, A.P.O. 303 Fort McPherson, Ga.	Maj.	U.S. Army
Green, Charles F.	1958 Vallejo St. San Francisco, Calif.	Lt.	Field Artillery
Greenham, Roy Leonard	Anglo-Iranian Oil Co. C.O.R., Ltd., 90 William St. Melbourne, Australia		R.A. Air Force
Gregory, J. N.	Box 243 San Angelo, Tex.	Lt.	Army Air Corps
Gutru, Robert J.	500 Keeny Evanston, Ill.	Ens.	U.S.N.R.
Haenke, M. Churchill	885 S. Lucerne Blvd. Los Angeles, Calif.	Avn. Cadet	Army Air Corps
Halbouty, Michel Thomas	5 W. Lane Houston, Tex.	Capt.	Army Air Corps
Hancock, Bob	Box 87 Yale, Okla.	Capt.	U.S. Army
Haring, Louis H., Jr.	1106 McCullough Ave. San Antonio, Tex.	Lt.	Army Air Corps

Name	*Home Address*	*Rank*	*Branch of Service*
Harrison, John W.	Argo Oil Corp., Denver, Colo.		Corps of Engineers
Hart, Raymond M.	111 N.E. Twenty-third St. Oklahoma City, Okla.		U.S. Army
Hawkins, Glenn Dewayne	423 S. Allegheny, Tulsa, Okla.	Lt.	U.S. Navy
Helis, James	2002 American Bank Bldg. New Orleans, La.	Lt.	U.S. Army
Helmig, Phil D.	131 Greer St. San Antonio, Tex.	Capt.	Army Air Corps
Herold, John S.	U.S.S. Wm. P. Biddle c/o Postmaster New York, N.Y.		U.S.N.R.
Hill, Orval Hall	Shell Oil Co., Inc., Box 1191 Tulsa, Okla.	Lt.	Army Air Corps
Hiller, C. F.	411 E. Belle, Rantoul, Ill.		Army Air Corps
Hinson, Hillord	1809 Dearborn St. Lawton, Okla.	Lt.	Field Artillery
Hoffer, Clarence W.	Rm. 4814, Navy Dept. Washington, D.C.	Lt. Com.	U.S.N.R.
Hopkins, Richard H.	Box 2038 Pittsburgh, Pa.	Lt.	Corps of Engineers
Hopper, Richard H.	7958 W. Norton Ave. Los Angeles, Calif.		U.S. Army
Hornkohl, Frank E.	Chemical Laboratories, Box 1673 Bakersfield, Calif.	Capt.	Army Air Corps
Hudson, William A.	1810 Electric Bldg. Fort Worth, Tex.		Ferry Command
Hunter, H. M.	1419 Ninth St. W. Calgary, Alta., Canada	Lt.	R. C. Army
Irwin, Carl B.	528 Adams Bldg. Port Arthur, Tex.	Ens.	U.S. Navy
Jackson, J. R., Jr.	Montgomery, Tex.	Lt.	Coast Artillery
Jager, Eric H.	235 N. Belmont Wichita, Kan.	Lt.	Tank Bn.
Jenkins, George Marvin	419 Magazine St. Tupelo, Miss.		U.S. Army
Johnson, Edward L.	1829 W. Summit San Antonio, Tex.	Capt.	Army Air Corps
Johnson, Edward W.	604 Central Ave. Faribault, Minn.	Lt.	Signal Corps
Jones, Charles T.	728 E. Miami Ave. McAlester, Okla.	Maj.	Corps of Engineers
Joujon-Roche, Jean Edward	512 Fontaine St. Alexandria, Va.	Lt.	Corps of Engineers
Kearny, Clinton C.	710 Grayson St. San Antonio, Tex.		Army Air Corps
Kelley, Frederic R.	Gen. Del., Belvedere, Calif.	Lt.	Army Air Corps
Kerr, James Lee	337 Eleanor San Antonio, Tex.	Ens.	U.S.N.R.
Ketterer, Walter P.	Hq., Hq. Sqn., A.A.F. Bolling Field, D.C.	Pvt.	Operational Int.
Kilbourne, Lewis P.	Wakefield, La.		Marine Corps
Kivi, Wilho J.	384th Eng. Bn. Fort Bragg, N.C.	Lt.	Corps of Engineers
Knight, Wilbur H.	310 S. Tenth St. Laramie, Wyo.	Lt.	Infantry
Kornfeld, M. M.	3015 Ruth St. Houston, Tex.	Pvt.	Army Air Corps
Kotick, O. F.	44th Inf. Div., A.P.O. 44 Fort Lewis, Wash.	Maj.	Infantry
Kreidler, William Lynn	Tide Water Assoc. Oil Co. Shreveport, La.		U.S. Navy
Kyle, Jerry R.	Carter Oil Co. Tulsa, Okla.	Lt.	Army Air Corps

Name	*Home Address*	*Rank*	*Branch of Service*
Leonard, Clarence Z.	201 E. Eighteenth St. Higginsville, Mo.		U.S. Army
Lester, John L.	350th F.A. Camp Livingston, La.	Lt.	Field Artillery
Levy, David J.	2217 Huldy St. Houston, Tex.	Pvt.	Army Air Corps
Liming, John A.	614th Tank Destroyer Bn. Camp Carson, Colo.	Lt.	Tank Destroyer Bn.
Little, Sterling E.	Rm. 27, Bldg. 701 Naval Air Base Jacksonville, Fla.	Avn. Cadet	U.S.N. Air Corps
Lueth, Clinton A.	1904 Milam Bldg. San Antonio, Tex.	Ens.	U.S.N. Air Corps
Loeblich, Alfred P., Jr.	Dept. of Geol., Tulane Univ. New Orleans, La.	Lt.	Field Artillery
Loring, Ralph C.	703 Fourth Ave. Asbury Park, N.J.		Signal Corps
Madden, Lloyd W.	718 Market St. Emporia, Kan.		U.S. Army
Mankin, Warren W.	Air Corps Tech. School Sheppard Field, Wichita Falls, Tex.	Lt.	Army Air Corps
Manthos, Atlee G.	U.S. Army Air Force Basic Flying School Waco, Tex.	Lt.	Army Air Corps
Mathes, Donald E.	756th Tank Bn. Fort Lewis, Wash.	Maj.	Tank Bn.
Mathews, John W.	Western Geophysical Co. Bakersfield, Calif.	Capt.	Corps of Engineers
Matthews, Charles L.	817 N. A St. Wellington, Kans.	Lt.	Infantry
Mauck, Melvin D.	R.R. 3, Princeton, Ind.	Lt.	Tank Bn.
Maxson, John H.	650 Subway Terminal Bldg. Los Angeles, Calif.	Capt.	Air Intelligence
Mayer, Maurice J.	1170 Park Blvd. Baton Rouge, La.	Pvt.	Army Air Corps
McAdams, R. E.	Shell Oil Co., Inc. San Antonio, Tex.	Lt.	Infantry
McClain, Forrest Milton	1408 Fourth Ave. Columbus, Ga.	Lt.	U.S. Army
McClure, Perry S.	R.R. 1 Elizabethtown, Ky.	Lt.	Signal Corps
McCobb, Harry W.	A.P.O. 501 San Francisco, Calif.	Maj.	U.S. Army
McCoy, George Y.	Republic Natl. Bank Dallas, Tex.	Lt.	Corps of Engineers
McCready, Harry J.	4923 Knox Court Denver, Colo.		U.S.N.R.
McKay, A. E.	1809 W. Broadway Enid, Okla.		Army Air Corps
McLendon, Dan Harvey	94th C.A. (AA) Langley Field, Va.		Coast Artillery
McMurtry, Wilbur Earl	Box 1936 Wichita, Kans.	Lt.	Field Artillery
McNab, James	Hq., Hq. Sqn., 5th Bomb. Grp. A.P.O. 838, c/o Postmaster New Orleans, La.	Lt.	Army Air Corps
McNaughton, D. A.	R 150,217, A. C. 2 Manning Depot No. 1, R.C.A.F. Toronto, Ont., Canada		R. C. Air Force
Messman, Robert L.	212 W. Eleventh Hays, Kans.	Sgt.	Medical Corps

Name	*Home Address*	*Rank*	*Branch of Service*
Michaelson, Louis H.	251 N. Poplar Wichita, Kans.	Avn. Cadet	Army Air Corps
Miles, Phil M.	808 S. St. Asaph St. Alexandria, Va.	Lt.	U.S. Army
Miller, Lloyd E.	c/o Mrs. A. Miller 4715 Pillsbury Ave. S. Minneapolis, Minn.	Ens.	U.S. Navy
Miller, P. W.	Box 421, Merkel, Tex.		Glider Pilot School
Ming, Raymond E.	U.S. Naval Air Station Quonset Point, R.I.	Lt.	U.S.N. Air Corps
Mohler, Donald P.	Humble Oil & Refg. Co. Amarillo, Tex.		Corps of Engineers
Monsour, Edward	2754 Lakeshore Dr. Shreveport, La.	Ens.	U.S.N.R.
Monsour, Emil	Air Corps Repl. Center Maxwell Field, Ala.	Lt.	Army Air Corps
Moody, John D.	635 Oneonta St. Shreveport, La.	Lt.	Marine Corps
Moorhead, Johnny Bob	1005 Eleventh St. Wichita Falls, Tex.	Ens.	U.S.N.R.
Morgan, Charles Gill	War Dept. Office Office of Chief of Air Corps Washington, D.C.	Major	Army Air Corps
Mortlock, Frank O.	c/o F. E. Mortlock 601 Clyde St. Pittsburgh, Pa.		U.S. Navy
Mullinax, Jack D.	Rt. 3, Chesnee, S.C.		Corps of Engineers
Munoz, Robert R.	Terrace Oil Co., Inc. 42 Broadway New York, N.Y.	Lt.	Military Intelligence Div.
Neely, Joseph	Lovell, Wyo.	Lt.	Infantry
Neiler, William Dixon	212 N. Thirtieth St. Billings, Mont.	Pvt.	U.S. Army
Newell, Donald F.	400 W. Washington Blair, Neb.	Capt.	Field Artillery
Newell, H. W.	2692 Landon Rd. Cleveland, Ohio	Lt.	U.S. Army
Nicholls, Wm. M.	746 Milam Bldg. San Antonio, Tex.	Capt.	Army Air Corps
Noland, Orval W.	c/o W. A. Noland Waukomis, Okla.	Lt.	Army Air Corps
Niven, Robert N.	Drawer 2100, Houston, Tex.	Lt.	Army Air Corps
Noll, Donald E.	Btry. H, 3rd Bn., 12th Marines 23rd Marines Rein. New River Tng. Center New River, N.C.	Lt.	Marine Corps
Orman, Freeman L. Jr.	Box 374, Austin, Tex.	App. Seaman	U.S. Navy
Orr, Mark L.	Idalou, Tex.		U.S.N. Air Corps
Owen, Edgar W.	532 Milam Bldg. San Antonio, Tex.	Capt.	Army Air Corps
Paige, Sidney	War Dept., Office of Div. Eng. N. Atlantic Div., 270 Broadway New York, N.Y.		Corps of Engineers
Park, Noel Robertson	338 N. Kings Rd. Los Angeles, Calif.	Pvt.	U.S. Army
Park, Stafford	4556 Graywood Ave. Long Beach, Calif.	Lt.	U.S.N.R.
Patterson, Luther Edwin, Jr.	1208 N.W. Thirty-sixth St. Oklahoma City, Okla.	Capt.	Field Artillery
Payne, Max	560 Haberfelde Bldg. Bakersfield, Calif.		U.S. Navy

Name	*Home Address*	*Rank*	*Branch of Service*
Pence, Richard H.	3554 Carlin Ave. Lynwood, Calif.	Lt. Com.	U.S. Navy
Penn, Wm. Y.	Petroleum Bldg. Midland, Tex.		U.S. Army
Pennel, H. David	Amerada Petr. Corp. Box 3, Lafayette, La.	Corp.	Corps of Engineers
Piggott, Guido M., Jr.	904 Old Natl. Bank Bldg. Evansville, Ind.		U.S. Army
Pinkley, George R.	144 Mariposa Dr. San Antonio, Tex.	Lt.	Chem. Warfare Corps
Pool, Frank M.	Combat Command B, Hq. 1st Armored Div. A.P.O. 251, c/o Postmaster New York, N.Y.		Armored Force
Porter, Phil	1000 Continental Bldg. Dallas, Tex.	Ens.	U.S. Navy
Potsch, John	U.S.S. Adamant, Section Base Morehead City, N.C.	Ens.	U.S. Navy
Prescott, Gordon W.	Corps of Engineers 89th Ordnance Co. Fort Leonard Wood, Mo.	Lt.	Corps of Engineers
Preston, J. Basil	Hq. Co., 80 A.R., 8th Arm'd Div., A.P.O. 258 Fort Knox, Ky.	Pvt.	Armored Forces
Punches, R. K.	269 Jackson St. Hempstead, N.Y.	Lt.	Corps of Engineers
Reed, Charles M.	229 Penhurst St. Rochester, N.Y.		U.S. Army
Reiss, John W.	1810 Sante Fe St. Corpus Christi, Tex.	Lt.	Army Air Corps
Relf, George O., Jr.	Box 175, Edmond, Okla.	Ens.	U.S. Navy
Renick, B. Coleman	1439 N.W. Thirty-eighth St. Oklahoma City, Okla.	Maj.	Army Air Corps
Revelle, Roger R. D.	Scripps Inst. of Oceanography La Jolla, Calif.	Lt.	U.S. Navy
Rhodes, Edward J.	Ordnance, Raritan Arsenal Metuchen, N.J.		U.S. Army
Rife, Byron	Office of Field Director of Ammunition Plants St. Louis, Mo.	Lt. Col.	U.S. Army
Roark, Louis Claude	2652 S. Trenton, Tulsa, Okla.		Army Air Corps
Robert, Charles V., Jr.	R.R. 1, Overton, Tex.		Army Air Corps
Robichaux, Douglas B.	Box 147 Jeanerrette, La.	Lt.	U.S. Army
Roper, Frank C.	c/o R. E. Neil, Jr. 509 Esperson Bldg. Houston, Tex.	Lt.	Army Air Corps
Ross, E. McIver	2148 Addison Rd., Houston, Tex.		Army Air Corps
Rumsey, Nelson J., Jr.	5463 Fair Oaks Ave. Pittsburgh, Pa.	Lt.	Army Air Corps
Russell, Harry J., Jr.	Gulf Oil Corp. 1107 Union Natl. Bank Bldg. Wichita, Kans.	Lt.	Army Air Corps
Ruwwe, John W.	3641 Bates St., St. Louis, Mo.	Ens.	U.S. Navy
Ryan, Thomas P.	Ordnance, Raritan Arsenal Metuchen, N.J.		U.S. Army
Samuell, John H.	409 S. Eddy St., Pecos, Tex.	Capt.	Army Air Corps
Sands, Charles D.	The Ohio Oil Co. Box 253, Lafayette, La.	Lt.	Corps of Engineers
Sartain, Max R.	1415 N.W. Thirty-fourth St. Oklahoma City, Okla.	Lt.	Army Air Corps

Name	*Home Address*	*Rank*	*Branch of Service*
Saville, Wilson G.	1348 Esperson Bldg. Houston, Tex.	Lt. Col.	Corps of Engineers
Schall, Fred M., Jr.	4834 St. Charles St. New Orleans, La.	Ens.	U.S.N.R.
Schneider, William T.	c/o R. M. Jones Honolulu Oil Corp. Midland, Tex.	Lt.	Corps of Engineers
Schweer, Henry	600 Eubanks Oklahoma City, Okla.	Capt.	Army Air Corps
Seals, Wilburn Hall	1609 Broadway New Orleans, La.	Ens.	U.S. Navy
Sheller, James Warner	Box 455 Studio City Sta. N. Hollywood, Calif.	Lt.	Coast Artillery
Shoemaker, Richard Walter	Ohio Oil Co., Box 193 Bakersfield, Calif.	Ens.	U.S.N.R.
Simmons, Rouse	418 Bartlett Bldg. Los Angeles, Calif.	Lt.	Army Air Corps
Skinner, John W.	Humble Oil & Refg. Co. Midland, Tex.		Glider Pilot School
Smith, Fred E.	San Antonio Avn. Cadet Cen. Group 12, Flight G. San Antonio, Tex.	Lt.	Army Air Corps
Snider, L. B.	717 Milam Bldg. San Antonio, Tex.	Capt.	Army Air Corps
Snyder, Raymond W.	751 Quebec, Denver, Colo.	Lt.	Army Air Corps
Sprengling, Kurt	1407 Sutherland Pl. Birmingham, Ala.	Lt.	U.S. Army
Stapp, Wilford Lee	Asst. Communications Officer Tyndale Field, Fla.	Lt.	U.S. Army
Stewart, Sam	825 S. LeDoux Rd. Los Angeles, Calif.	Avn. Cadet	Army Air Corps
Stolz, H. P.	c/o Stanley & Stolz 510 S. Spring St. Los Angeles, Calif.	Lt. Com.	U.S. Navy
Stone, R. O.	1420 S. Fifth St. Alhambra, Calif.	Lt.	Army Air Corps
Stone, Solon W.	235 E. Eighty-third St. New York, N.Y.	Ens.	U.S.N.R.
Stotler, Raymond T.	Ambassador Hotel 7 W. Fourteenth St. Tulsa, Okla.	Lt.	Army Air Corps
Suffield, Harry F.	OCC Dept. of Tactics Fort Sill, Okla.	Capt.	Field Artillery
Swesnik, Robert Malcolm	1528 N. Western Oklahoma City, Okla.	Lt.	Armored Force
Swiger, Rual B.	Nixon Bldg. Corpus Christi, Tex.	Capt.	Army Air Corps
Taber, Edward C., Jr.	Military Intelligence Camp Savage, Minn.		Military Intelligence Div.
Tarr, Russell S.	2244 E. Twenty-Fifth Pl. Tulsa, Okla.	Capt.	Army Air Corps
Taylor, M. Hall	701 S. Grand Ave. Lyons, Kan.	Lt.	Tank Destroyer Bn.
Teichman, Joseph B.	210 Maple Terrace Dallas, Tex.	Lt.	Army Air Corps
Tennis, Langdon C.	614 W. Storey, Midland, Tex.		Army Air Corps
Thomas, Ralph N.	2625 Newman St. Ashland, Ky.	Lt.	U.S. Army
Terrill, J. V.	Box 1461, Midland, Tex.	Capt.	Ferry Command
Thrasher, Glen C.	Co. D, 1st Bn., 382nd. Inf. Camp Adair, Ore.	Pvt.	Infantry, U.S. Army

Name	*Home Address*	*Rank*	*Branch of Service*
Thams, Wm. H.	1311 Boston, Muskogee, Okla.	Lt.	Field Artillery
Tichy, James R.	328 S. Seventeenth St. Lincoln, Neb.	Ens.	U.S.N.R.
Tobin, Don Freeman	907 Milam Bldg. San Antonio, Tex.	Ens.	U.S. Navy
Todd, John D.	3633 Wickersham Lane Houston, Tex.	Lt.	Army Air Corps
Tompkins, Joseph D.	Box 1332 Midland, Tex.	Capt.	Ferry Command
Tuck, Louis L.	2201 Broadway Mt. Vernon, Ill.	Avn. Cadet	U.S. Navy
Uhrig, Leonard F.	Maintenance Bn., 5th A.D. Camp Cooke, Lompoc, Calif.	Lt.	U.S. Army
Vesely, Leon R.	Amerada Petroleum Corp. 1811 Esperson Bldg. Houston, Tex.	Lt.	U.S. Army
Wadsack, George E., Jr.	1517 Oklahoma Ave. Norman, Okla.		U.S. Army
Waters, Joyce Irene	Box 2175, Houston, Tex.		Women's Naval Reserve
Wells, Harris Peyton, Jr.	220 Minnesota Ave. Buffalo, N.Y.		Corps of Engineers
Wengerd, Sherman A.	Div. of Air Navigation Hydrographic Office Washington, D.C.	Lt.	U.S.N.R.
Whorton, Chester D.	Box 311 Coudersport, Pa.	Lt.	U.S.N.R.
Wilder, Newell M.	155 Hamilton Park Lexington, Ky.	Lt.	Infantry
Willis, Clifford L.	U.S. Coast Guard Res. Officer Tng. School Yeaton Hall, New Haven, Conn.		Coast Guard
Wilson, James, Jr.	Box 87, Rockdale, Tex.	Lt.	Cavalry, U.S. Army
Winkler, Hans	104 W. Thirty-second St. Austin, Tex.	Lt.	U.S.N. Air Corps
Wiringa, Leon O.	Armed Guard Center (Pacific) Treasure Island San Francisco, Calif.	Ens.	U.S. Navy
Wofford, Henry R., Jr.	234 W. Mistletoe San Antonio, Tex.	Sgt.	U.S. Army
Wold, John S.	c/o Dr. P. I. Wold Union College Schenectady, N.Y.	Ens.	U.S.N.R.
Woods, R. D.	c/o Mrs. C. C. Woods Box 167, Lisbon, La.		U.S. Army
Woodward, T. P.	693 Canal St. Baton Rouge, La.		Field Artillery
Yarborough, Hunter, Jr.	Rm. 242, Bldg. 661 Naval Air Station Pensacola, Fla.	Ens.	U.S. Navy
Zadik, Jacob W.	Baker Oil Tools, Inc. Box 312, Olney, Ill.	Lt.	Field Artillery

MEMBERS OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS EMPLOYED BY THE UNITED STATES AND ALLIED COUNTRIES IN CIVILIAN WORK

Allardyce, Robert L., Jr., Jr. Eng., Lone Star Ordnance Works, Texarkana, Tex.
Anderson, Carl C., U. S. Bureau of Mines, Box 2250, Amarillo, Tex.
Avery, C. Dwight, U. S. Geol. Survey, 3240 Interior Bldg., N., Washington, D. C.
Bain, H. Foster, U. S. Bureau of Mines, Manila, P. I.
Baker, Arthur A., U. S. Geol. Survey, Washington, D. C.
Baker, Norval E., Office of Petr. Coordinator, Rm. 1104, 122 E. Forty-second St., New York, N.Y.
Barnett, J. A., U. S. Geol. Survey, Roswell, N. Mex.
Bass, Nathan, W., U. S. Geol. Survey, Box 311, Tulsa, Okla.
Bateman, Alan M., Bureau of Economic Warfare, Washington, D. C.
Bennett, Robert R., U. S. Geol. Survey, Div. of Ground Water, Washington, D. C.
Best, J. Boyd, Office of Petr. Coordinator, Mellie Esperson Bldg., Houston, Tex.
Billings, Martin Hewett, c/o Non-metal Economics Div., U. S. Bureau of Mines, Dept. of Interior, Washington, D. C.
Blank, Horace R., Soil Conservation Service, Box 26, Waco, Tex.
Bowles, Edgar O., U. S. Geol. Survey, Washington, D. C. (temporary address, Univ. Station, Tucson, Ariz.)
Brazil, James Joseph, U. S. Coast & Geodetic Survey, Baltimore, Md.
Brodie, Gerson H., U. S. Geol. Survey, Bath, Me.
Brown, Glen Francis, U. S. Geol. Survey, Box 653, University, Miss.
Buck, E. O., Office of Petr. Coordinator for War, 245 Esperson Bldg., Houston, Tex.
Butterworth, E. M., Special Representative, Office of Petr. Coordinator, Foreign Div., 33 E. Forty-eighth St., New York, N. Y.
Carpenter, Charles B., U. S. Bureau of Mines, Dallas, Tex.
Cederstrom, D. John, U. S. Geol. Survey, Charlottesville, Va.
Cerkel, J. David, U. S. Geol. Survey, Bin CC, Taft, Calif.
Coleman, Tom L., U. S. Geol. Survey, Box 976, Oklahoma City, Okla.
Corby, Grant W. (employed by Philippine Govt.—present address unknown)
Crawford, James Gilmore, U. S. Dept. of Interior, Federal Bldg., Casper, Wyo.
Crickmay, Geoffrey W., Apt. 501 W, Clifton & Fourteenth Sts., N. W., Washington, D. C. (Production Requirements Plan, Branch of War Production Board)
Dane, Charles H., U. S. Geol. Survey, Washington, D. C.
Darton, N. H., U. S. Geol. Survey, Washington, D. C.
De Golyer, Ass't Deputy Coordinator, Office of Petr. Coordinator, Washington, D. C.
Dickerson, Roy E., Sr. Analyst, Petr. Div., Tech. Br., Board of Economic Warfare, Arlington, Va.
Dobbin, Carroll E., U. S. Geol. Survey, 224 Custom House, Denver, Colo.
Drach, Gertrude M., Office of Petr. Coordinator for Natl. Defense, Prod. Div., Interior Bldg., Washington, D. C.
Duce, James Terry, Office of Petr. Coordinator for Natl. Defense, Foreign Div., New Interior Bldg., Washington, D. C.
Erdmann, Charles E., U. S. Geol. Survey, 224 Custom House, Denver, Colo.
Espach, Ralph H., U. S. Bureau of Mines, Box 877, Laramie, Wyo.
Farish, Linn M., Civilian Tech. Corps, Great Britain (3546 Seventy-fourth St., Jackson Heights, Long Island, N. Y.)
Farrell, Agnes M., U. S. Geol. Survey, Washington, D. C.
Fender, Hollis B., Dept. of Soil Investigation, Wabash River Ordnance Works, Bloomington, Ind.
Gardner, Julia, U. S. Geol. Survey, Washington, D. C.
Guthrie, Robert K., U. S. Bureau of Mines, 551 Federal Bldg., Dallas, Tex.
Hard, Edward W., Board of Economic Warfare, Washington, D. C.
Hawkins, Harold H., National Park Service, Richmond, Va.
Henbest, Lloyd G., Room 327, U. S. Natl. Museum, Washington, D. C.
Henderson, Charles W., U. S. Bureau of Mines, 515 Custom House, Denver, Colo.
Hendricks, Thomas A., U. S. Geol. Survey, Washington, D. C.
Hendy, William J., U. S. Engineers, Vicksburg, Miss.
Heroy, William B., Director, Div. of Reserves, Office of Petr. Coordinator, Washington, D. C.
Heston, J. Ed., Office of Prod. Management, Alexandria, Va.
Hill, Harry B., U. S. Bureau of Mines, 551 Federal Bldg., Dallas, Tex.
Hoffman, M. G., Office of Petr. Coordinator, Washington, D. C.
Holmer, Ralph C., Physicist, Naval Bureau of Ordnance, Charleston, S. C.
Hough, Jack Luin, Soil Conservation Service, Houston, Tex.
Hughes, Richard V., Office of Petr. Coordinator, Washington, D. C.

Hume, George S., Geol. Survey of Canada, Ottawa, Ont., Canada
Imlay, Ralph W., U. S. Geol. Survey, 331 U. S. Natl. Museum, Washington, D. C.
Janovy, John, U. S. Engineers, Tulsa, Okla.
Jones, Paul Hastings, U. S. Geol. Survey, Ground Water Div., Box 8315, Univ. Sta., Baton Rouge, La.
Kane, William G., Apt. 197, Saltillo, Coah., Mexico
King, Philip B., U. S. Geol. Survey, Washington, D. C.
Knechtel, M. M., U. S. Geol. Survey, Room 4230, N. Interior Bldg., Washington, D. C.
Kramer, William B., U. S. Geol. Survey, 224 Custom House, Denver, Colo.
Krumbein, William C., Beach Erosion Board, Little Falls Rd., N. W., Washington, D. C.
Long, W. B., U. S. Geol. Survey, Washington, D. C.
Larrabee, David M., U. S. Geol. Survey, Hanover, N. H.
Larsen, Raymond M., U. S. Geol. Survey, 305 Federal Bldg., Casper, Wyo.
Lee, Marvin, Office of Petr. Coordinator, Chicago, Ill.
Lewis, J. Volney, c/o H. B. McCoy, Bureau of Foreign & Domestic Commerce, Washington, D. C.
Lott, Frederick S., Petr. Economics Div., U. S. Bureau of Mines, 202 Federal Bldg., Bartlesville, Okla.
Loughlin, Gerald F., U. S. Geol. Survey, Washington, D. C.
Martin, B. G., Office of Petr. Coordinator, 245 Mellie Esperson Bldg., Houston, Tex.
Martin, George C., Exec. Secretary, U. S. Board on Geographical Names, Dept. of Interior, Washington, D. C.
Maverick, Phillip, Securities & Exchange Commission, Room 103, U. S. Courthouse, Fort Worth, Tex.
Maxwell, Ross A., Region III, Headquarters, National Park Service, Santa Fe, N. Mex.
McGhee, George C., U. S. Exec. Secretary, Combined Raw Materials Board, Washington, D. C.
McWhirt, Burr, Income Tax Unit, Room 3232, Internal Revenue Bldg., Washington, D. C.
Mendenhall, Walter C., U. S. Geol. Survey, Washington, D. C.
Merritt, Roy W., American Embassy, Bogota, Colombia, S. A.
Millard, William John, 4224 Hastings St., El Paso, Tex. (B.E.W., Prin. Prod. Spec., U. S. Embassy, Rio de Janeiro, Brazil, S. A.)
Miller, John Robson, U. S. Geol. Survey, Box 27, Limerick, Me.
Milner, Charles A., Jr., Natl. Park Service, Ardmore, Okla.
Miser, Hugh D., U. S. Geol. Survey, Washington, D. C.
Monahan, Charles Joseph, U. S. Engineer Office, Little Rock, Ark.
Monroe, Watson G., U. S. Geol. Survey, Washington, D. C.
Montgomery, Don D., Ordnance Dept., Aberdeen Proving Grounds, Md.
Needham, Claude E., Economics & Statistics Br., U. S. Bureau of Mines, Washington, D. C.
Newhouse, Lester, U. S. Engineer Office, A.P.O. 805, St. Lucia, B. W. I.
Ongley, Montague, New Zealand Geol. Survey, 156 Terrace, Wellington, N. Z.
Page, Lincoln R., U. S. Geol. Survey, Washington, D. C.
Parker, Garald Gordon, U. S. Geol. Survey, 6323 N. W. Miami Pl. Miami, Fla.
Payne, Thomas G., Alaska Branch, U. S. Geol. Survey
Pierce, William Gamewell, U. S. Geol. Survey, Washington, D. C.
Pike, Sumner T., Securities & Exchange Commission, Rittenhouse Square, Philadelphia, Pa.
Reeside, John Bernard, Jr., U. S. Geol. Survey, Washington, D. C.
Robbins, H. Weston, Soil Conservation Service, Torrington, Wyo.
Rodgers, John, U. S. Geol. Survey, Washington, D. C.
Rose, Nicholas A., U. S. Geol. Survey, Houston, Tex.
Rothrock, Howard E., Natl. Park Service, U. S. Dept. of Interior, Washington, D. C.
Russell, R. Dana, Univ. of Calif., Div. of Natl. Defense Research, U. S. Navy Radio and Sound Lab., San Diego, Calif.
Sayre, A. Nelson, U. S. Geol. Survey, Washington, D. C.
Scherer, Oliver J., Soil Conservation Service, Lincoln, Nebr.
Schwabrow, John R., U. S. Geol. Survey, Box 565, Thermopolis, Wyo.
Sears, Julian D., U. S. Geol. Survey, Washington, D. C.
Severy, C. L., U. S. Bureau of Mines, Washington, D. C.
Shelton, John S., U. S. Geol. Survey, Washington, D. C.
Sherbondy, William E., 2425 W. Thirty-fifth Ave., Denver Colo. (Jr. Topographer, U. S. Geol. Survey)
Singewald, Joseph T., Jr., 213 Tunbridge Rd., Baltimore, Md. (Bureau of Economic Warfare)
Singewald, Quentin D., Univ. of Rochester, N. Y. (Bureau of Economic Warfare)
Sinnott, Allen, U. S. Geol. Survey, 5373 E. Second St., Long Beach, Calif.
Smith, James A., U. S. Geol. Survey, 704 City Hall, Houston, Tex.
Smith, Marcus A. J., Iowa Ordnance Plant, Army, Burlington, Iowa

Sohn, Israel G., Room 17, U. S. Natl. Museum, Washington, D. C.
Somers, George B., Geophysicist, Bureau of Ordnance, Fort Wayne, Ind.
Speed, C. D., Jr., Office of Petr. Coordinator, Washington, D. C.
Spratt, Robert Elmer, U. S. Geol. Survey, 208 Custom House, Denver, Colo.
Stephenson, L. W., U. S. Geol. Survey, Washington, D. C.
Stipp, Thomas F., U. S. Geol. Survey, Taft, Calif.
Storm, L. W., U. S. Bureau of Mines, on Mexican Resources.
Stringfield, V. T., U. S. Geol. Survey, Washington, D. C.
Thomas, J. Elmer, Spec. Ass't. to Deputy Coordinator, Office of Petr. Coordinator, Washington, D. C.
Trask, Parker D., U. S. Geol. Survey, Washington, D. C.
Ulrich, E. O., U. S. Natl. Museum, Washington, D. C.
Van Orstrand, C. E., U. S. Geol. Survey, Washington, D. C.
Vaughn, T. Wayland, U. S. Natl. Museum, Room 427, Washington, D. C.
Waring, Gerald A., U. S. Geol. Survey, Washington, D. C.
Weeks, Albert W., Office of Petr. Coordinator, 320 First Natl. Bank Bldg., Denver, Colo.
Whitcomb, Bruce, Federal Power Commission, Fort Worth, Tex.
White, Paul C., Federal Power Commission, Eighteenth & K St. Annex, Washington, D. C.
White, Tell T., Securities & Exchange Commission, Rittenhouse Square, Eighteenth & Locust Sts., Philadelphia, Pa.
Whittier, William H., Special Agent, Div. of Investigations, Dept. of Interior, Salt Lake City, Utah
Wilson, Ivan F., U. S. Geol. Survey, Ukiah, Calif.
Woodbury, Homer Olwin, U. S. Bureau of Mines, Boulder, Colo.
Wrather, W. E., Spec. Work in Bureau of Economic Warfare, Washington, D. C.
Wright, William Josiah, Dept. of Lands & Mines, Federicton, N. B., Canada
Wright, Randall, U. S. Engineer Office, M & M Bldg., Houston, Tex.
Yenne, Keith A., U. S. Coast & Geodetic Survey, Fort Morgan, Colo.
Zapp, Alfred D., U. S. Geol. Survey, Americus, Ga.
Zorichak, Joseph J., Office of Petr. Coordinator, Denver, Colo.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 26, NO. 10 (OCTOBER, 1942), PP. 1692-1696

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

ROBERT L. MCCORMICK, formerly with the Plymouth Oil Company at Sinton, Texas, is now research assistant in petroleum and natural gas engineering at Pennsylvania State College. He may be addressed in care of the Mineral Industries Building, State College, Pennsylvania.

JARVIS GARST, recently connected with Plymouth Oil Company, Sinton, Texas, may now be addressed at 1134 Commerce Building, Union Oil Company of California, Houston, Texas.

WALTER P. KETTERER is working in the Division of Operational Intelligence, Photo Intelligence Section. His new address is Hq. and Hq. Squadron A.A.F., Bolling Field, D. C.

WILLIAM LYNN KREIDLER of Tide Water Associated Oil Company in Shreveport, Louisiana, has joined the navy and is somewhere in the Pacific.

FRED M. SCHALL, JR., is an ensign in the navy and may be addressed at 4834 St. Charles Avenue, New Orleans, Louisiana.

ROLAND F. HODDER, formerly with the Brown Geophysical Company, is now employed as a geologist with the Lone Star Steel Corporation of Dallas, Texas.

E. D. LUMAN resigned as chief geologist of the Atlantic Refining Company, and is conducting independent operations. His address is 4661 Wenonah Drive, Dallas, Texas.

LOUIS C. CHAPPUIS is a captain in the Air Intelligence Service. During his absence, his consulting office will be in charge of H. S. DUMKE.

EDWARD L. JOHNSON, consulting geologist of San Antonio, Texas, is a captain in the Air Corps at Miami Beach, Florida.

HARLAN W. PEABODY, geologist with the Mid-Continent Petroleum Corporation and its predecessor, the Cosden Oil and Gas Company, since 1917, resigned, effective September 1. He plans to look after private interests and may engage in independent activity. His home is 1716 South Detroit Avenue, Tulsa, Oklahoma.

HOMER C. MOORE, of the geophysical department of The Texas Company at Houston, was appointed head of the geophysical and geological department of Mid-Continent Petroleum Corporation, Tulsa, Oklahoma, effective September 1.

W. G. CLARKSON, JR., of the Ohio Oil Company at Midland, Texas, is taking the officer's training course in the Coast Guard.

W. DOW HAMM, assistant manager of exploration for the Shell Oil Company, Inc., in the Gulf Coast division, has resigned to become chief geologist for the Atlantic Refining Company at Dallas, Texas, succeeding E. B. LUMAN, who resigned. GORDON H. WHITE, Shell geologist for the San Antonio, Tyler, and Shreveport districts, succeeds Hamm.

J. N. GREGORY, consulting geologist at San Angelo, Texas, is a first lieutenant in the Army Air Corps.

The new million-dollar Mineral Industries Building of the University of West Virginia will be dedicated at the beginning of the 76th academic year, October 16 and 17, at Morgantown. The two upper floors of the six-story structure will be occupied by the department of geology and the geological survey of both of which PAUL H. PRICE is head.

G. H. CROWL, of the department of geology at Princeton University, is an instructor in geology at Vanderbilt University, Nashville, Tennessee.

GEORGE S. COREY, of the Shell Oil Company, Inc., Midland, Texas, is a first lieutenant in the Army Air Force.

RALPH C. LORING, who has been with the International Petroleum Company in Ecuador, is working as a civilian in the Signal Corps at Camp Evans, Belmar, New Jersey,

C. F. HILLER, formerly geologist with The Texas Company at Wichita Falls, Texas, is an instructor in the Army Air Force Technical Training School at Chanute Field, Illinois.

RICHARD H. HOPKINS, of the Gulf Research and Development Company, Pittsburgh, Pennsylvania, is a second lieutenant in overseas service.

M. E. HOOVER has returned from Calcutta, India, and may be addressed at 700 Lancaster Building, Calgary, Alberta.

ROY E. DICKERSON has moved from Upper Darby, Pennsylvania, to 1305 North Adams Street, Arlington, Virginia. He is senior analyst in the petroleum division, technical branch, of the Board of Economic Warfare.

MILO M. ORR, district geologist for the Superior Oil Company, Laredo, Texas, died last month. He joined the Association in 1920.

DONALD B. EICHER has recently returned from Cairo, Egypt, where he was connected with The Standard Oil Company of Egypt, and may be addressed at 3141 Home Avenue, Berwyn, Illinois.

W. C. KRUMBEIN has been appointed senior geologist of the Beach Erosion Board of the War Department, and is now engaged in war work in Washington. He has taken a leave of absence from the University of Chicago for the duration, and may be addressed at the Beach Erosion Board, Little Falls Road, N. W., Washington, D. C.

CECIL G. LALICKER, of the University of Oklahoma, was associated with the geological department of the Phillips Petroleum Company in Shreveport, Louisiana, during the summer months.

LEWIS S. CORYELL, district geologist for the Cities Service Oil Company, died September 15 at his home in Wichita Falls, Texas. He had been a member of the Association since 1920.

J. E. ELLIOTT, of Houston, Texas, who has been in Los Angeles most of the past year promoting the "indoor oil-field" project, has been commissioned a major in the Army Specialist Corps and assigned to the Atlanta Chemical Warfare Procurement District. His address is 430 West Peachtree Street, N. W., Atlanta, Ga.

M. M. KORNFELD is a private in the Air Corps, at present assigned to 398 Technical School Squadron, Flight A, Keesler Field, Mississippi.

A. VAN WEELDEN, chief geophysicist of the B.P.M. (Royal Dutch), whose permanent address is London, has been travelling in the Americas for a few months.

RUSSELL TARR, consulting geologist and operator of Tulsa, Oklahoma, has been appointed a captain in the Army Air Corps.

E. LEHNER wrote in June that he was able to leave Burma and his best present address is Burmah Oil Company, 25 Warris Road, Lahore, British India.

JULE H. WALKER, formerly with the Superior Oil Corporation at Houston, is employed as a scout for the Ohio Oil Company, San Antonio, Texas.

JOHN SMITH IVY, consulting geologist, described "The Tinsley Field, Mississippi," to the Houston Geological Society, September 17.

NORVAL E. BAKER, of the Near East Development Corporation, is in the Office of the Petroleum Coördinator, Room 1104, 122 East Forty-second Street, New York City.

GERALD H. WESTBY, C.A.P. Northwestern Oklahoma group commander and president of the Seismograph Service Corporation, and William G. Green, C.A.P. state training and operations officer, and president of Engineering Service, Inc., both of Tulsa, Oklahoma, have been commissioned as captains by the National Civilian Patrol in Washington, D. C.

J. L. CHASE is leaving the navy as civilian navy inspector and resuming private work. His address is 169 LaVerne Avenue, Long Beach, California.

MISS JOYCE IRENE WATERS, of the Schlumberger Well Surveying Corporation, Houston, Texas, has joined the Women's Naval Reserve.

President F. L. AURIN spoke on "The Place of the Geologist in the War Effort," at the first fall luncheon meeting of the Fort Worth Geological Society.

New officers of the Oklahoma City Geological Society are: president, H. TRAVIS BROWN, Cities Service Oil Company; vice-president, LESTER L. WHITING, The Texas Company; secretary-treasurer, I. CURTIS HICKS, Phillips Petroleum Company.

L. CLARK MORGAN, of Wichita, Kansas, has joined the geological staff of the National Refining Company.

FRANK A. OYSTER has opened a consulting office at 910 Union National Bank Building, Wichita, Kansas.

DONALD D. HUGHES, consultant of Los Angeles, California, has been appointed Acting Associate Professor of Geology at Stanford University for the academic year. He will temporarily replace Simon W. Muller who is in special service for the War Department in Washington, D. C.

WILLIAM E. WRATHER is now associate chief of the Metals and Minerals Division, Board of Economic Warfare, Washington, D. C.

C. J. HARES spoke on "The Genesis of the Sherman Hill Flat Surface, Laramie Mountains, Wyoming," at the meeting of the Rocky Mountain Association of Petroleum Geologists on October 5.

J. Q. ANDERSON, recently with the Union Oil Company of California, has accepted a position with The Texas Company in charge of the geological office, Coalinga, California.

A. F. CRIDER gave an illustrated talk on the "History of the Shreveport Geological Society," at the first annual meeting of the Society in Shreveport, Louisiana, on October 2.

E. E. BROSSARD, errecently with the Mene Grande Oil Company, Caracas, Venezuela. South America, may be addressed at 1130 Erin Street, Madison, Wisconsin.

CHANGE IN THE APPLICATIONS FOR COMMISSIONS IN THE AIR CORPS

On account of new regulations, the appointment of civilians as commissioned officers in the Air Corps has become rather complicated, and it is our understanding that no additional applications will be considered at this time.

Some of the applications have gone forward and have been approved and commissions granted. The others are now frozen under the new orders which require all commissions to be granted to enlisted personnel who are graduates of Officers' Candidate Schools.

There is no indication that exceptions will be made to this new rule; however, we are hopeful that in view of the fact that there is probably a need for a substantial number of qualified interpreters of aerial photographs, Intelligence Officers and Map Officers in the Air Corps, that this regulation will be modified to the extent of further consideration of the other applicants. All inquiries should, at least for the present, be directed to the Adjutant General's office where they have been filed.

I have been instructed by Lieutenant Colonel Charles G. Morgan to notify all geologists who are qualified for interpreters of aerial photographs, Intelligence and Map Officers and who are about to be inducted into the Armed Forces, that they should go to their local draft boards and state that they have the above qualifications and would like to be placed in the Air Corps on induction. It is my understanding that the local draft boards have been instructed to consider technical qualifications in the placement of men in the different branches of military service. When they are inducted into the Air Corps, they should immediately notify Lieutenant Colonel Charles G. Morgan, Room 742, Annex No. 1, Gravelly Point, Washington, D. C., and F. L. Aurin 1607 Trinity Building, Fort Worth, Texas.

If this procedure is followed, there is a good possibility of being acceptable for officers training and commissions in the above work in the Air Corps. If on the other hand, they are inducted into other branches of Service, a transfer as outlined above is not so certain.

IMPORTANT SUPPLEMENTAL INFORMATION ON CHANGE IN APPLICATIONS FOR INTERPRETERS OF AERIAL PHOTOGRAPHS AND INTELLIGENCE OFFICERS IN THE AIR CORPS

Supplementing the information on the change in applications for interpreters of aerial photographs and intelligence officers in the Air Corps as now appearing in this bulletin, please note the following:

Considerable confusion has occurred in the applications of draft inductees in their contacts with the local draft boards in that these boards have advised in many cases that they have no authority to recommend or place draft inductees in any branch of the service, and also that they have no instructions to recognize technical qualifications. In view of this situation, Lt. Col. Charles G. Morgan was contacted and he has advised that geologists qualified for interpreters of aerial photographs and intelligence officers in the Air Corps to proceed as follows.

After the draftee has received notice (1) that he is to be inducted on a definite date, and (2) that he is to be sent to a Reception Center (name and location of same), then,

and only then, when he has definite information on both these items, he is to wire Lt. Col. Morgan, Room G-742, Annex No. 1, Gravelly Point, Washington, D. C., and he will see that the qualified inductees will be assigned to the Air Corps soon after arriving at the Reception Center. After being assigned to the Air Corps from the Reception Center, Colonel Morgan should be notified of such assignment and the place of assignment and he will give further instructions.

It is also our understanding that former commissioned officers and reserve officers, not now in military service and who are qualified as interpreters of aerial photographs and intelligence officers in the Air Corps, can make application for commissioned officers in the Air Corps and that such applicants communicate with Colonel Morgan in doing so. It would be helpful if such applicants give a brief history of their training and experience qualifying them for this type of work.

PROFESSIONAL DIRECTORY

Space for Professional Cards Is Reserved for Members of the Association. For Rates Apply to A.A.P.G. Headquarters, Box 979, Tulsa, Oklahoma

CALIFORNIA

PAUL P. GOUDKOFF
Geologist

Geologic Correlation by Foraminifera and Mineral Grains

799 Subway Terminal Building
LOS ANGELES, CALIFORNIA

ERNEST K. PARKS
Consultant in
Petroleum and Natural Gas Development
and
Engineering Management

614 S. Hope St.
LOS ANGELES, CALIFORNIA

HENRY SALVATORI

Western Geophysical Company

711 Edison Building
601 West Fifth Street
LOS ANGELES, CALIFORNIA

R. L. TRIPLETT

Contract Core Drilling

WHitney 9876 2013 West View St.
LOS ANGELES, CALIF.

COLORADO

C. A. HEILAND
President
Heiland Research Corporation

Geophysical Equipment
Industrial and Scientific Instruments

130 East Fifth Avenue
DENVER, COLORADO

HARRY W. OBORNE
Geologist

304 Mining Exchange Bldg. 230 Park Ave.
Colorado Springs, Colo. New York, N.Y.
Main 7525 Murray Hill 9-3541

EVERETT S. SHAW

Geologist - Engineer

3131 Zenobia Street
DENVER, COLORADO

Exploration Surveys

ILLINOIS

ELMER W. ELLSWORTH
Consulting Geologist

Wham Building
212 East Broadway
CENTRALIA, ILLINOIS

L. A. MYLIUS

Geologist *Engineer*

140½ S. Poplar St.

Box 264, Centralia, Illinois

INDIANA

NATHAN C. DAVIES
Petroleum Geologist and Engineer
Specializing in Subsurface Conditions and Correlations and in Production Problems
2232 E. Powell, Evansville, Indiana

IOWA

ALLEN C. TESTER
Geologist
State University
of Iowa, Iowa City

KANSAS

L. C. MORGAN
Petroleum Engineer and Geologist
Specializing in Acid-Treating Problems
207 Ellis-Singleton Building
WICHITA, KANSAS

LOUISIANA

WILLIAM M. BARRET, INC.
Consulting Geophysicists
Specializing in Magnetic Surveys
Giddens-Lane Building SHREVEPORT, LA.

CYRIL K. MORESI
Consulting Geologist
Carondelet Bldg. New Orleans, La.

NEW YORK

FREDERICK G. CLAPP
Consulting Geologist
Examinations, Reports, Appraisals, Management
50 Church Street New York
Chickasha Oklahoma

BROKAW, DIXON & McKEE
Geologists *Engineers*
OIL—NATURAL GAS
Examinations, Reports, Appraisals
Estimates of Reserves
120 Broadway New York
Gulf Building Houston

OHIO

JOHN L. RICH
Geologist
Specializing in extension of "shoestring" pools
University of Cincinnati
Cincinnati, Ohio

OKLAHOMA

ELFRED BECK
Geologist

717 McBirney Bldg.
TULSA, OKLA.

Box 55
DALLAS, TEX.

GEOLOGIC AND STRUCTURAL MAPPING FROM AERIAL PHOTOGRAPHS

LOUIS DESJARDINS
Aero-Geologist

739 Kennedy Bldg. Tulsa, Oklahoma

R. W. Laughlin L. D. Simmons

WELL ELEVATIONS

LAUGHLIN-SIMMONS & CO.
615 Oklahoma Building
TULSA OKLAHOMA

R. L. GINTER
Owner

GINTER LABORATORY
CORE ANALYSES
Permeability
Porosity
Reserves
118 West Cameron, Tulsa

CLARK MILLISON
Petroleum Geologist
Beacon Building
TULSA OKLAHOMA

A. I. LEVORSEN
Petroleum Geologist
221 Woodward Boulevard
TULSA OKLAHOMA

G. H. WESTBY
Geologist and Geophysicist
Seismograph Service Corporation
Kennedy Building Tulsa, Oklahoma

C. L. WAGNER
Consulting Geologist
Petroleum Engineering
Geophysical Surveys
2259 South Troost Street
TULSA OKLAHOMA

PENNSYLVANIA

HUNTLEY & HUNTLEY
Petroleum Geologists and Engineers
L. G. HUNTLEY
J. R. WYLIE, JR.
Grant Building, Pittsburgh, Pa.

TEXAS

JOSEPH L. ADLER
Geologist and Geophysicist
Contracting Geological, Magnetic, Seismic and Gravitational Surveys
901 Esperson Bldg.
HOUSTON, TEXAS

D'ARCY M. CASHIN
Geologist *Engineer*
Specialist, Gulf Coast Salt Domes
Examinations, Reports, Appraisals
Estimates of Reserves
705 Nat'l. Standard Bldg.
HOUSTON, TEXAS

TEXAS

CUMMINS & BERGER
Consultants
Specializing in Valuations
Texas & New Mexico
1601-3 Trinity Bldg. Ralph H. Cummins
Fort Worth, Texas Walter R. Berger

E. DEGOLYER
Geologist
Esperson Building
Houston, Texas
Continental Building
Dallas, Texas

ALEXANDER DEUSSEN
Consulting Geologist
Specialist, Gulf Coast Salt Domes
1006 Shell Building
HOUSTON, TEXAS

DAVID DONOGHUE
Consulting Geologist
Appraisals - Evidence - Statistics
Fort Worth National Bank Building FORT WORTH, TEXAS

ROBERT H. DURWARD
Geologist
Specializing in use of the magnetometer and its interpretations
1431 W. Rosewood Ave. San Antonio, Texas

J. E. (BRICK) ELLIOTT
Petroleum Engineer
3404 Yoakum Blvd. Houston, Texas

F. B. Porter, *President* R. H. Fash, *Vice-President*
THE FORT WORTH LABORATORIES
Analyses of Brines, Gas, Minerals, Oil. Interpretation of Water Analyses. Field Gas Testing.
828½ Monroe Street FORT WORTH, TEXAS
Long Distance 138

W. G. SAVILLE J. P. SCHUMACHER A. C. PAGAN
GRAVITY METER EXPLORATION CO.
TORSION BALANCE EXPLORATION CO.
Gravity Surveys
Domestic and Foreign
1347-48 ESPERSON BLDG. HOUSTON, TEX.

CECIL HAGEN
Geologist
Gulf Bldg. HOUSTON, TEXAS

L. B. HERRING
Geologist
Natural Gas .....Petroleum
DRISCOLL BLDG. CORPUS CHRISTI, TEXAS

J. S. HUDNALL G. W. PIRTLE
HUDNALL & PIRTLE
Petroleum Geologists
Appraisals Reports
Peoples Nat'l. Bank Bldg. TYLER, TEXAS

JOHN S. IVY
Geologist
1124 Niels Esperson Bldg., HOUSTON, TEXAS

TEXAS

W. P. JENNY

Consulting Geologist and Geophysicist

Specializing in MICROMAGNETIC SURVEYS, GEOLOGICAL INTERPRETATIONS and CORRELATIONS of seismic, gravimetric, electric and magnetic surveys.

1404 Esperson Bldg. HOUSTON, TEXAS

MID-CONTINENT TORSION BALANCE SURVEYS
SEISMIC AND GRAVITY INTERPRETATIONS

KLAUS EXPLORATION COMPANY
H. KLAUS
Geologist and Geophysicist

115 South Jackson, Enid, Oklahoma
2223 15th Street, Lubbock, Texas

JOHN D. MARR

Geologist and Geophysicist

SEISMIC EXPLORATIONS, INC.

Gulf Building Houston, Texas

DABNEY E. PETTY

10 Tenth Street

SAN ANTONIO, TEXAS

No Commercial Work Undertaken

ROBERT H. RAY
ROBERT H. RAY, INC.

Geophysical Engineering

Gravity Surveys and Interpretations

Gulf Bldg. Houston, Texas

F. F. REYNOLDS

Geophysicist

SEISMIC EXPLORATIONS, INC.

Gulf Building Houston, Texas

E. E. ROSAIRE
SUBTERREX
BY
Geophysics and Geochemistry

Esperson Building Houston, Texas

WEST VIRGINIA

DAVID B. REGER

Consulting Geologist

217 High Street

MORGANTOWN WEST VIRGINIA

WYOMING

E. W. KRAMPERT

Geologist

P.O. Box 1106

CASPER, WYOMING

DIRECTORY OF GEOLOGICAL AND GEOPHYSICAL SOCIETIES

For Space Apply to A.A.P.G. Headquarters
Box 979, Tulsa, Oklahoma

COLORADO

ROCKY MOUNTAIN ASSOCIATION OF PETROLEUM GEOLOGISTS
DENVER, COLORADO

President - - - - - - - - H. E. Christensen
The Texas Company
1st Vice-President - - - - - C. E. Erdmann
U. S. Geological Survey
2nd Vice-President - - - - - Don B. Gould
Colorado College, Colorado Springs
Secretary-Treasurer - - - - Ralph D. Copley
1006 U. S. National Bank Building

Dinner meetings, first and third Mondays of each month, 6:15 P.M., Auditorium Hotel.

ILLINOIS

ILLINOIS GEOLOGICAL SOCIETY

President - - - - - - - - C. B. Anderson
Gulf Refining Company, Box 482, Mattoon

Vice-President - - - - - - Darsie A. Green
The Pure Oil Company, Box 311, Olney

Secretary-Treasurer - - - - - - V. C. Scott
The Texas Company, Box 476, Mattoon

Meetings will be announced.

INDIANA-KENTUCKY

INDIANA-KENTUCKY GEOLOGICAL SOCIETY

President - - - - - - - Edmund T. Benson
Tide Water Associated Oil Company
Evansville, Indiana

Vice-President - - - - - - - R. R. Munoz
Terrace Oil Company, Evansville, Indiana

Secretary-Treasurer - - - - Edward J. Combs
Sun Oil Company
Evansville, Indiana

Meetings will be announced.

KANSAS

KANSAS GEOLOGICAL SOCIETY
WICHITA, KANSAS

President - - - - - - - - George D. Putnam
Lario Oil and Gas Company
Vice-President - - - - - - William C. Imbt
Stanolind Oil and Gas Company
Secretary-Treasurer - - - - - - Z. E. Stucky
Cities Service Oil Company
Manager of Well Log Bureau - Harvel E. White

Regular Meetings: 7:30 P.M., Geological Room, University of Wichita, first Tuesday of each month. Visitors cordially welcomed.

The Society sponsors the Kansas Well Log Bureau which is located at 412 Union National Bank Building.

LOUISIANA

THE SHREVEPORT GEOLOGICAL SOCIETY
SHREVEPORT, LOUISIANA

President - - - - - - - - James D. Aimer
Arkansas Fuel Oil Company

Vice-President - - - - - - - - Joseph Purzer
Phillips Petroleum Company

Secretary-Treasurer - - - - Van D. Robinson
Atlantic Refining Company, 1001 City Bank Bldg.

Meets the first Monday of every month, October to May, inclusive, 7:30 P.M., Civil Courts Room, Caddo Parish Court House. Special dinner meetings by announcement.

SOUTH LOUISIANA GEOLOGICAL SOCIETY
LAKE CHARLES, LOUISIANA

President - - - - - - - - - - Harry Kilian
Union Sulphur Company, Sulphur, La.
Vice-President - - - - - - - Coe S. Mills
Ohio Oil Company, Lafayette, La.
Secretary - - - - - - - - - - Roy A. Payne
Gulf Refining Company, Lake Charles, La.
Treasurer - - - - - - - - George N. May
Union Sulphur Co., Sulphur, La.

Meetings: Luncheon 1st Wednesday at Noon (12:00) and business meeting third Tuesday of each month at 7.00 P.M. at the Majestic Hotel. Visiting geologists are welcome.

MICHIGAN

MICHIGAN GEOLOGICAL SOCIETY

President - - - - - - - - - Lee C. Lamar
Carter Oil Company, Mt. Pleasant

Vice-President - - - - - - - A. J. Eardley
University of Michigan, Ann Arbor

Secretary-Treasurer - - - Edward J. Baltrusaitis
Box 811, Saginaw

Business Manager - - - - Gordon H. Pringle
Ohio Oil Company, Mt. Pleasant

Meetings: Second Wednesday of month at 6:30 P.M., from November to April. Informal dinner followed by discussions. Meetings held in rotation, at Lansing, Mt. Pleasant, Ann Arbor, Grand Rapids. Visiting geologists are welcome.

MISSISSIPPI

MISSISSIPPI GEOLOGICAL SOCIETY
JACKSON, MISSISSIPPI

President - - - - - - - - Tom McGlothlin
Gulf Refining Company, Box 1105

Vice-President - - - - - - David C. Harrell
Carter Oil Company, Box 1490

Secretary-Treasurer - - - - - A. A. Holston
Stanolind Oil and Gas Company, Box 689

Meetings: First and third Wednesdays of each month, from October to May, inclusive, at 7:30 P.M., Edwards Hotel, Jackson, Mississippi. Visiting geologists welcome to all meetings.

OKLAHOMA

ARDMORE GEOLOGICAL SOCIETY
ARDMORE, OKLAHOMA

President - - - - - - - - Paul L. Bartram
Phillips Petroleum Company

Vice-President - - - George C. Hollingsworth
Independent Producer

Secretary-Treasurer - - - - - Frank Neighbor
Sinclair Prairie Oil Company

Asst. Secretary-Treasurer - - - C. E. Hannum
The Texas Company

Dinner meetings will be held at 7:00 P.M. on the first Wednesday of every month from October to May, inclusive, at the Ardmore Hotel.

OKLAHOMA CITY GEOLOGICAL SOCIETY
OKLAHOMA CITY, OKLAHOMA

President - - - - - - - - H. Travis Brown
Cities Service Oil Company, Box 4577

Vice-President - - - - - Lester L. Whiting
The Texas Company, Box 354

Secretary-Treasurer - - - - - I. Curtis Hicks
Phillips Petroleum Company
1211 First National Building

Meetings: Technical program each month, subject to call by Program Committee, Oklahoma City University, 24th Street and Blackwelder. Luncheons: Every Thursday, at 12:00 noon, Skirvin Hotel Coffee Shop.

SHAWNEE GEOLOGICAL SOCIETY
SHAWNEE, OKLAHOMA

President - - - - - - - Robert L. Cassingham
Amerada Petroleum Corporation

Vice-President - - - - - - - - U. R. Laves
Consulting Geologist, 723 S. Broadway, Ada, Okla.

Secretary-Treasurer - - - - - Martyna Garrison
Amerada Petroleum Corporation

Meets the fourth Monday of each month at 8:00 P.M., at the Aldridge Hotel. Visiting geologists welcome.

THE STRATIGRAPHIC SOCIETY OF TULSA
TULSA, OKLAHOMA

President - - - - - - - - - Ralph A. Brant
Atlantic Refining Company, Beacon Building

(Meetings discontinued until further notice)

TULSA GEOLOGICAL SOCIETY
TULSA, OKLAHOMA

President - - - - - - - - Glenn Scott Dillé
Consulting Geologist, Atlas Life Building

1st Vice-President - - - - - Maurice R. Teis
The Ohio Oil Company

2nd Vice-President - - - - Myron C. Kiess
The Pure Oil Company

Secretary-Treasurer - - - Louis H. Desjardins
Aero-Geologist, 739 Kennedy Bldg.

Editor - - - - - - - - - Constance Leatherock
Tide Water Associated Oil Company

Meetings: First and third Mondays, each month, from October to May, inclusive, at 8:00 P.M., University of Tulsa, Kendall Hall Auditorium. Luncheons: Every Thursday (October-May), Michaelis Cafeteria, 507 South Boulder Avenue.

TEXAS

DALLAS PETROLEUM GEOLOGISTS
DALLAS, TEXAS

President - - - - - - - - - J. A. Lewis
Core Laboratories, Inc., Santa Fe Building

Vice-President - - - - - - - C. C. Albritton
Southern Methodist University

Secretary-Treasurer - - - - - Barney Fisher
Coronado Corporation

Executive Committee - - - - Fred A. Joekel
Magnolia Petroleum Company, Box 900

Meetings: Regular luncheons, first Monday of each month, 12:15 noon, Petroleum Club, Adolphus Hotel. Special night meetings by announcement.

TEXAS

EAST TEXAS GEOLOGICAL SOCIETY

TYLER, TEXAS

President - - - - - - - - C. I. Alexander
Magnolia Petroleum Company, Box 780

Vice-President - - - - - - - E. B. Wilson
Sun Oil Company, Box 807

Secretary-Treasurer - - - - Laurence Brundall
Shell Oil Company, Inc., Box 2037

Meetings: Monthly and by call.
Luncheons: Every Monday at 12:00 noon, Blackstone Hotel.

FORT WORTH GEOLOGICAL SOCIETY

FORT WORTH, TEXAS

President - - - - - - - - - J. B. Lovejoy
Gulf Oil Corporation

Vice-President - - - - - - - Karl A. Mygdal
The Pure Oil Company

Secretary-Treasurer - - - Richard H. Schweers
The Texas Company

Meetings: Luncheon at noon, Worth Hotel, every Monday. Special meetings called by executive committee. Visiting geologists are welcome to all meetings.

HOUSTON GEOLOGICAL SOCIETY

HOUSTON, TEXAS

President - - - - - - Carleton D. Speed, Jr.
Consulting Geologist, Second National Bank Bldg.
Vice-President - - - - - - Donald M. Davis
Pure Oil Company
Secretary - - - - - - - Wayne Z. Burkhead
Union Oil Company of California
1134 Commercial Building
Treasurer - - - - - - James W. Kisling, Jr.
Amerada Petroleum Corporation, Esperson Bldg.
Regular meeting held every Thursday at noon (12 o'clock), Mezzanine floor, Texas State Hotel. For any particulars pertaining to the meetings write or call the secretary.

NORTH TEXAS GEOLOGICAL SOCIETY

WICHITA FALLS, TEXAS

President - - - - - - - - - Robert Roth
Humble Oil and Refining Company

Vice-President - - - - - - - - F. E. Melott
Deep Rock Oil Company

Secretary-Treasurer - - - - - Dolphe E. Simic
Cities Service Oil Company

Luncheons and evening programs will be announced.

SOUTH TEXAS GEOLOGICAL SOCIETY

SAN ANTONIO, TEXAS

President - - - - - - - W. W. Hammond
Magnolia Petroleum Company, 1709 Alamo National Building, San Antonio
Vice-President - - - - - - - J. M. Hancock
Southern Minerals Corporation, Corpus Christi
Secretary-Treasurer - - - - - Wm. H. Curry
Wellington Oil Company, 1108 South Texas Bank Building, San Antonio

Meetings: Third Tuesday of each month in San Antonio. Luncheon every Monday noon at Milam Cafeteria, San Antonio, and at Plaza Hotel, Corpus Christi.

WEST TEXAS GEOLOGICAL SOCIETY

MIDLAND, TEXAS

President - - - - - - - Ronald K. DeFord
Argo Oil Corporation

Vice-President - - - - - Bernerd A. Ray
Tide Water Associated Oil Company

Secretary-Treasurer - - - William M. Osborn
Consulting Geologist, Box 707

Meetings will be announced

WEST VIRGINIA

THE APPALACHIAN GEOLOGICAL SOCIETY

CHARLESTON, WEST VIRGINIA
P. O. Box 2385

President - - - - - - - Charles Brewer, Jr.
Godfrey L. Cabot, Inc., Box 1473
Vice-President - - - - - - - H. J. Wagner
Public Service Commission
Secretary-Treasurer - - - - - R. S. Hyde
West Virginia Gas Corporation
Box 404, Charleston, W.Va.
Editor - - - - - - - - Robert C. Lafferty
Owens, Libbey-Owens Gas Department
4007 Staunton Ave., Charleston, W.Va.
Meetings: Second Monday, each month, except June, July, and August, at 6:30 P.M., Kanawha Hotel.

THE SOCIETY OF EXPLORATION GEOPHYSICISTS

President - - - - - - - - Frank Goldstone
Shell Oil Company, Inc., Houston, Texas

Vice-President - - - - - - - R. D. Wyckoff
Gulf Research and Development Company
Pittsburgh, Pennsylvania

Editor - - - - - - - - - J. A. Sharpe
Stanolind Oil and Gas Company, Tulsa, Oklahoma

Secretary-Treasurer - - - - - T. I. Harkins
Independent Exploration Company, Houston, Texas

Past-President - - - - - - - H. B. Peacock
Geophysical Service, Inc., Houston, Texas

Business Manager - - - - - - J. F. Gallie
P.O. Box 2585, Houston, Texas

REPORT OF A SYMPOSIUM ON PETROLEUM DISCOVERY METHODS

CONDUCTED BY THE RESEARCH COMMITTEE, A. I. LEVORSEN, CHAIRMAN, AT THE 27TH ANNUAL MEETING OF THE ASSOCIATION, AT DENVER, APRIL 21, 1942

164 PP. LITHOPRINTED. 8.5 x 11 INCHES. PAPER COVER

PRICE, $1.00, POSTPAID

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
BOX 979, TULSA, OKLAHOMA, U.S.A.

The Annotated

Bibliography of Economic Geology
Vol. XIV, No. I

Orders are now being taken for the entire volume at $5.00 or for individual numbers at $3.00 each. Volumes I-XIII can still be obtained at $5.00 each.

The number of entries in Vol. XIII is 1,995.

Of these, 465 refer to *petroleum, gas,* etc., and *geophysics.* They cover the world.

If you wish future numbers sent you promptly, kindly give us a *continuing* order.

An Index of the 10 volumes was issued in May, 1939. Price: $5.00

Economic Geology Publishing Co.
Urbana, Illinois, U.S.A.

THE JOURNAL OF GEOLOGY

a semi-quarterly

Edited by

ROLLIN T. CHAMBERLIN

Since 1893 a constant record of the advance of geological science. Articles deal with problems of systematic, theoretical, and fundamental geology. Each article is replete with diagrams, figures, and other illustrations necessary to a full scientific understanding.

$6.00 a year
$1.00 a single copy

Canadian postage, 25 cents
Foreign postage, 65 cents

THE UNIVERSITY OF CHICAGO PRESS

FIRST IN OIL FINANCING

1895—1942

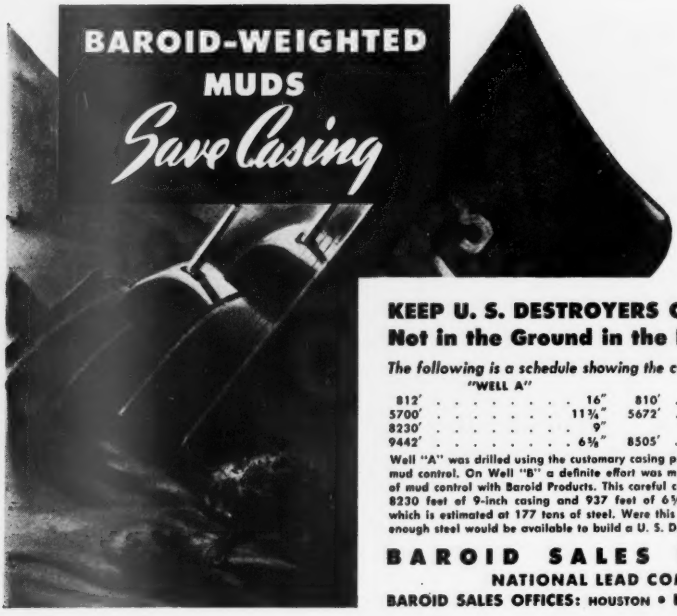
The FIRST NATIONAL BANK
and Trust Company of Tulsa

MEMBER FEDERAL DEPOSIT INSURANCE CORPORATION

THE GEOTECHNICAL CORPORATION

Roland F. Beers
President

1702 Tower Petroleum Building
Telephone L D 711 **Dallas, Texas**



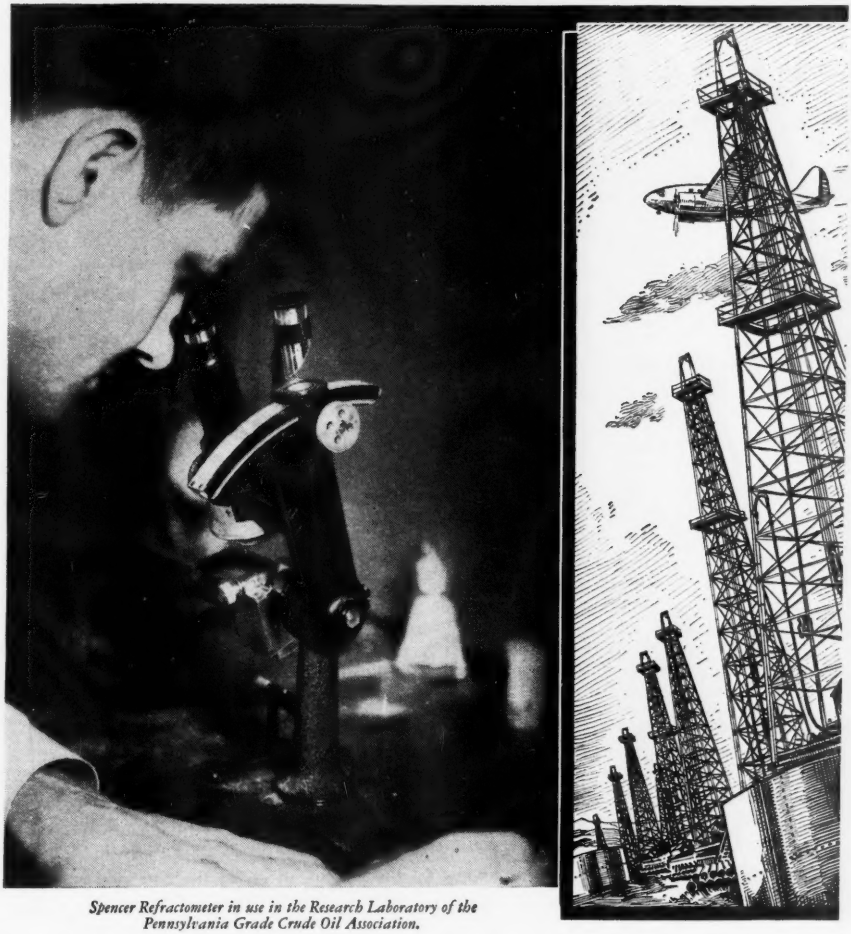
KEEP U. S. DESTROYERS ON THE SEAS—
Not in the Ground in the Form of Casing

The following is a schedule showing the casing used on two wells:

"WELL A"		"WELL B"	
812'	16"	810'	16"
5700'	11¾"	5672'	11¾"
8230'	9"	Saved	
9442'	6⅝"	8505' (Saved 937 feet)	6⅝"

Well "A" was drilled using the customary casing program and without particular mud control. On Well "B" a definite effort was made to save casing by means of mud control with Baroid Products. This careful control resulted in a saving of 8230 feet of 9-inch casing and 937 feet of 6⅝-inch casing, the weight of which is estimated at 177 tons of steel. Were this saving effected in four wells, enough steel would be available to build a U. S. Destroyer to help lick the Japs.

BAROID SALES DIVISION
NATIONAL LEAD COMPANY
BAROID SALES OFFICES: HOUSTON • LOS ANGELES • TULSA



Spencer Refractometer in use in the Research Laboratory of the Pennsylvania Grade Crude Oil Association.

Oil for Today's Strategy

Modern warfare depends upon lubricants for every phase of transportation and combat. Aircraft operating low over scorching deserts or in below-zero temperatures of the sub-stratosphere; ships at sea under forced draft; tanks, trucks and armored cars carrying heavy loads at high speeds; all these require specialized lubricants and fuels developed for their varying needs.

Research Laboratories in the Petroleum Industry are at work constantly, producing new and better lubricants and fuels to serve the United Nations—using the finest optical instruments to insure the highest quality.

★ ★ ★

Optical instruments are so vital to war and public health that the nation's needs absorb practically all of Spencer's greatly increased production.

★ ★ ★

Spencer LENS COMPANY
BUFFALO, NEW YORK
SCIENTIFIC INSTRUMENT DIVISION OF
AMERICAN OPTICAL COMPANY

PRACTICAL PETROLEUM ENGINEERS' HANDBOOK

SECOND EDITION

Revised and Enlarged

By JOSEPH ZABA, E.M.M.Sc.

and

W. T. DOHERTY

This book was written by practical oil men. The tables were compiled so that they can be used by anyone to meet practical field situations without further calculations, and will fit 99% of the conditions under which the average operator is working in the field.

The second edition of the PRACTICAL PETROLEUM ENGINEERS' HANDBOOK has been completely revised and enlarged. The many changes which have been made during the past two years in the Standard Specifications of the American Petroleum Institute, particularly in pipe specifications, are incorporated in the new edition. Several tables are rearranged and charts enlarged to facilitate their use. Table of Contents and Index are more complete. Also about 90 pages of new formulae, tables, charts and useful information have been added.

This handbook was compiled and published for the purpose of saving the time of operators, engineers, superintendents, foremen and others.

TABLE OF CONTENTS

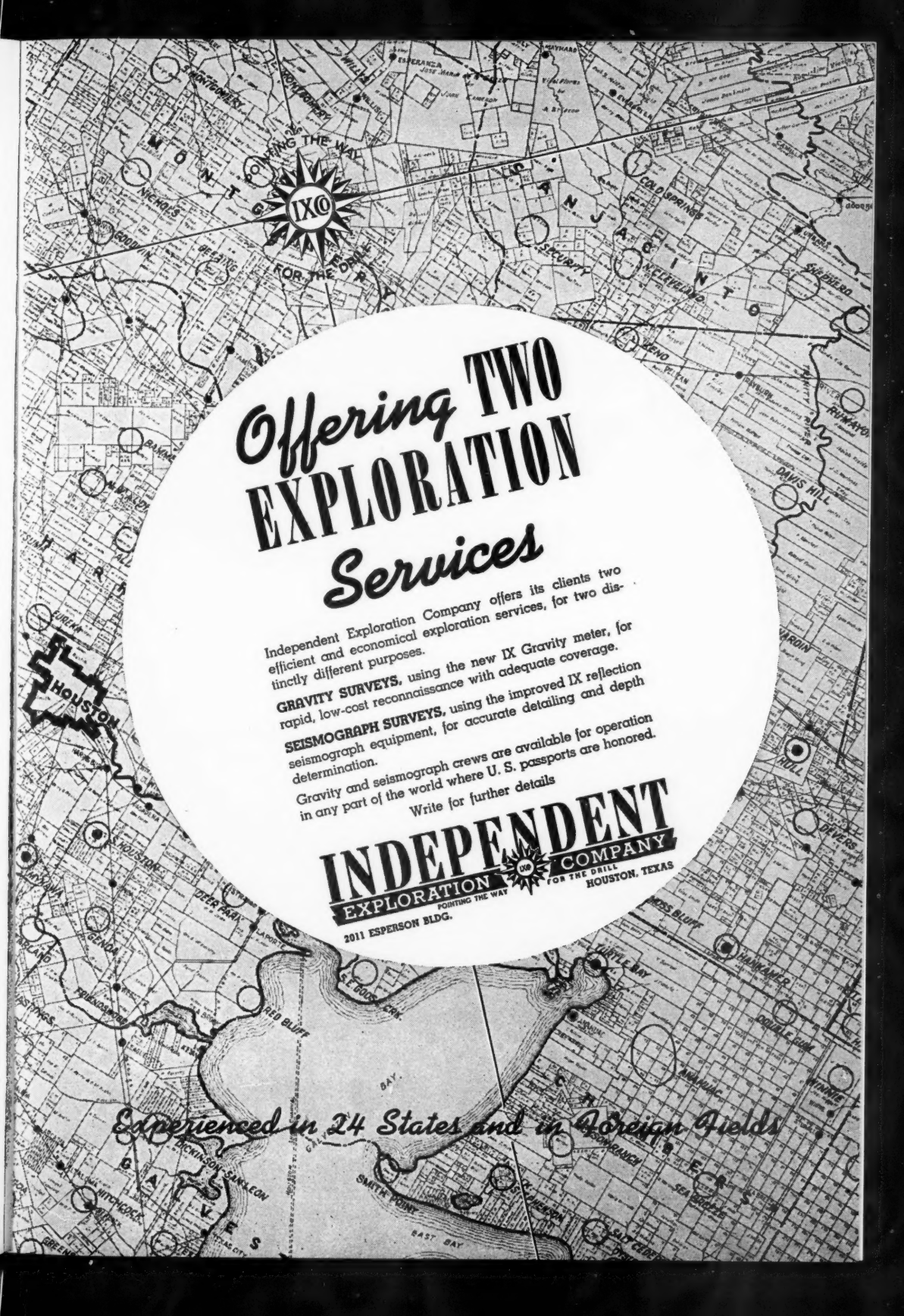
Chapter I —General Engineering Data
Chapter II —Steam
Chapter III —Power Transmission
Chapter IV —Tubular Goods
Chapter V —Drilling
Chapter VI —Production
Chapter VII —Transportation

Semi-Flexible Fabrikoid Binding, size 6 x 9, 492 Pages. Price: $5.00 Postpaid

Send Checks to the

GULF PUBLISHING COMPANY

P. O. BOX 2608, HOUSTON, TEXAS


Offering TWO EXPLORATION Services
Independent Exploration Company offers its clients two efficient and economical exploration services, for two distinctly different purposes.
GRAVITY SURVEYS, using the new IX Gravity meter, for rapid, low-cost reconnaissance with adequate coverage.
SEISMOGRAPH SURVEYS, using the improved IX reflection seismograph equipment, for accurate detailing and depth determination.
Gravity and seismograph crews are available for operation in any part of the world where U. S. passports are honored.
Write for further details
INDEPENDENT
EXPLORATION COMPANY
POINTING THE WAY
FOR THE DRILL
HOUSTON, TEXAS
2011 ESPERSON BLDG.
Experienced in 24 States and in Foreign Fields

UNITED

offers *all* these extra values

EQUIPMENT FOR ALL TYPES OF OPERATIONS ★ *Reflection Seismograph—Refraction Surveys—Dip Shooting—Continuous Profile—Three-dimensional Surveys*

UNEXCELLED RESEARCH FACILITIES *for development of the most advanced methods and equipment*

ACCURATE INTERPRETATION TECHNIQUE ★ *backed by highly successful results in many different localities*

EXPERIENCE IN BOTH DOMESTIC AND OVERSEAS SURVEYS ★ *under a wide range of difficult field conditions*

A STRICTLY INDEPENDENT CONSULTING ORGANIZATION ★ *having no connection with any petroleum interest*

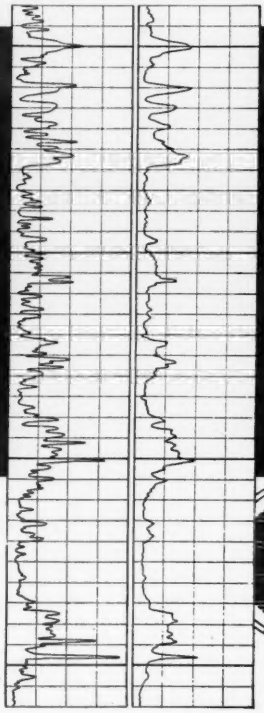
UNITED GEOPHYSICAL COMPANY

1255 East Green Street, Pasadena, California ★ 420 Lexington Avenue, New York City, N. Y
Esperson Building, Houston, Texas ★ 805 Thompson Building, Tulsa, Oklahoma
Rua Mexico No. 74, Rio de Janeiro, Brazil

LANE-WELLS *Electrolog* DETAIL CURVE MEETS THE GROWING DEMAND FOR ACCURATE REPRESENTATION OF PRODUCING HORIZONS • • •

THE "DETAIL" CURVE

The "DETAIL" Curve measures the resistance of the formation within a small sphere surrounding a single electrode. Being the most confined measurement it provides the maximum possible detail or response to thin formations. In conjunction with Electrolog's accurate measuring device, this curve indicates the precise depth of all formations from six inches up in thickness. This high degree of response makes possible the correlation of small changes in long shale sections where such correlation would otherwise be impossible.



THE "AVERAGING" CURVE

The "AVERAGING" Curve, of the single electrode potential type, is designed to reduce the complication of response of complex formations for easier correlation. This curve may be suited to the particular area to indicate just the right amount of detail on the log. Normal penetration is from 1½ to 3 feet, providing response to beds of two feet and over in thickness, eliminating thinner formations. By this means thicker formations are made to stand out against flat shale base lines, and correlation of complex sections is simplified.

Today's demands for efficient production require exacting knowledge as to the amount of sand in producing horizons. The Lane-Wells Electrolog "DETAIL" Shallow Penetration Resistivity Curve is designed to indicate thin sands and shales with the greatest fidelity. It provides the maximum detail and the sharpest indications of formation variations. This high degree of response makes possible the accurate determination of sand and shale percentages in producing zones as well as correlation in monotonous sections. For particular areas where excessive detail complicates correlation the "AVERAGING" Shallow Penetration Resistivity Curve is available.

For complete information about these exclusive Electrolog advantages, call your Lane-Wells Field Engineer.

TECHNICAL OILFIELD SERVICES

YOU SHOULD HAVE THIS BULLETIN!

Fighting Tomorrow's Tools-Today!

LANE-WELLS

Serving the Oil Industry

General Office and Export Office: 5610 South Soto Street, Los Angeles

FEDRALITE PLASTIC SHOT HOLE CASING

- LIGHT WEIGHT
- STRENGTH
- IMPROVED STEEL COUPLING
- LONG LIFE
- SAFETY
- ECONOMY

PROVED "OK" FOR EVERY SHOT HOLE DEPTH

New "no thread" Steel Coupling combines with inherent tensile and impact strength to give Fedralite Plastic Shot Hole Casing STRENGTH TO SPARE.

Today's trend toward deeper shot holes, especially in the marshy gulf coast area, brings new demands for strong, light weight casing . . . casing that will do the job safely, economically. Fedralite Plastic Shot Hole Casing is the answer.

This plastic casing is new and should not be confused with any other plastic casing offered in the past. It is thoroughly field proven, and features a new, "no thread" steel coupling that gives it an overall strength much greater than its own weight for any depth hole. And, even though Fedralite Plastic Shot Hole Casing does release vital steel supplies, it was not designed as a "war time substitute." It is a revolutionary improvement on shot hole casing, and offers advantages not to be overlooked.

Economies just begin with the surprisingly low price. Highest percentage possible is recovered for re-use, and the damaged section from shot is readily removed in the field without shop expense.

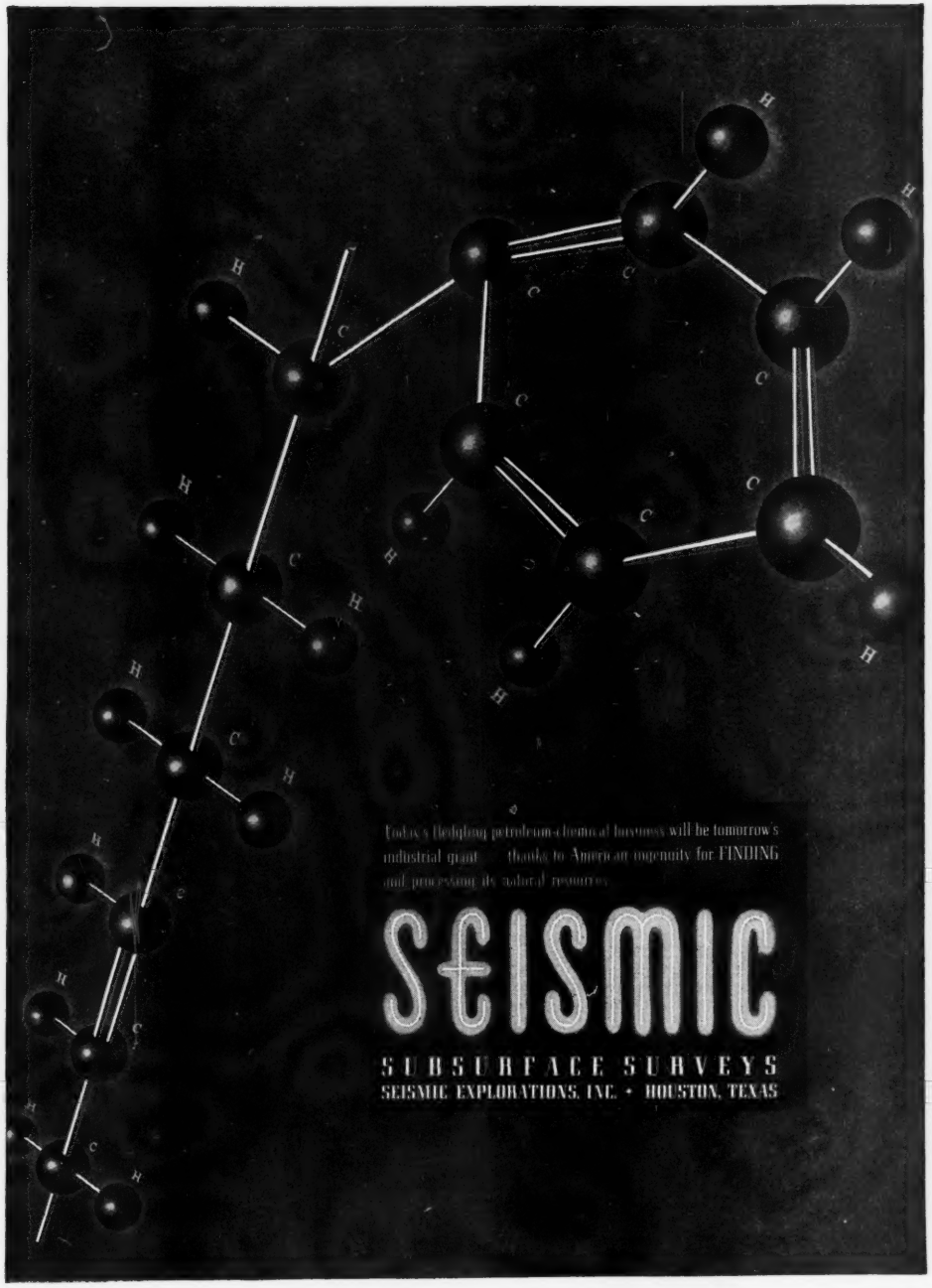
WRITE FOR COMPLETE INFORMATION AND PRICES

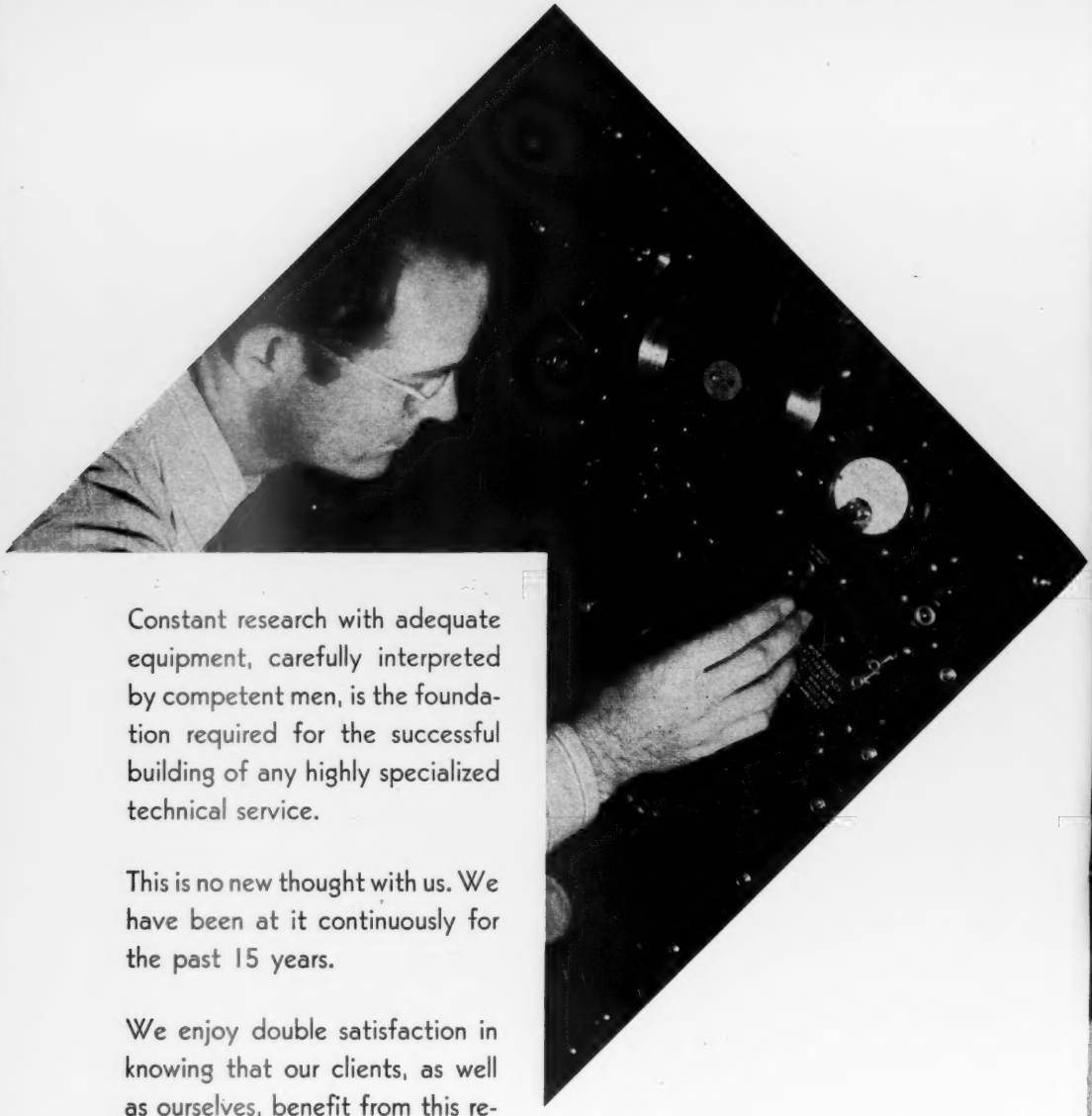
Immediate delivery from large Houston stocks

FEDERAL ELECTRIC COMPANY, INC.

PLASTIC DIVISION

700 Waugh Drive, HOUSTON 8700 S. State Street, CHICAGO


Today's fledgling petroleum-chemical business will be tomorrow's
industrial giant — thanks to American ingenuity for FINDING
and processing its natural resources
SEISMIC
SUBSURFACE SURVEYS
SEISMIC EXPLORATIONS, INC. • HOUSTON, TEXAS



Constant research with adequate equipment, carefully interpreted by competent men, is the foundation required for the successful building of any highly specialized technical service.

This is no new thought with us. We have been at it continuously for the past 15 years.

We enjoy double satisfaction in knowing that our clients, as well as ourselves, benefit from this research.

•

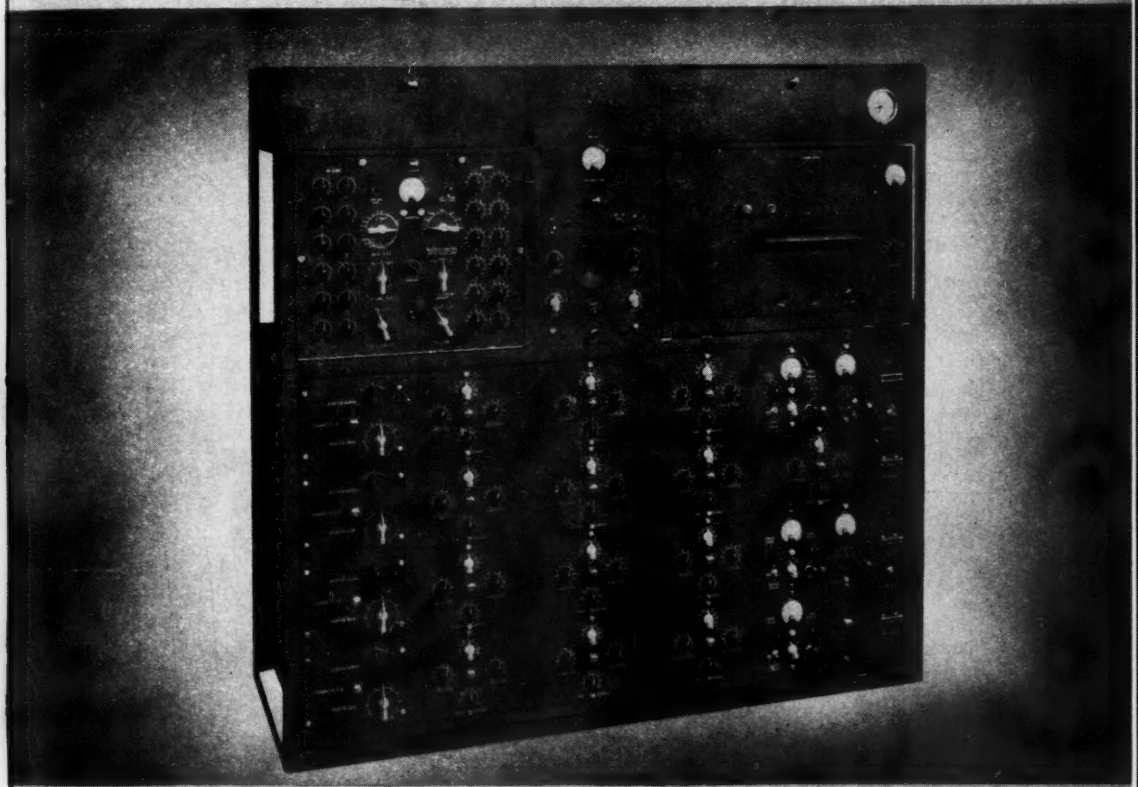
MAGNETIC AND ELECTRIC SURVEYS

WILLIAM M. BARRET, INC.

Consulting Geophysicists

GIDDENS-LANE BLDG., SHREVEPORT, LA.

Western Pioneers
Multiple Recording



ANOTHER WESTERN GEOPHYSICAL ADVANCEMENT

Features of the new 24-trace MULTIPLE RECORDING SEISMOGRAPH UNIT

★

1. *Completely automatic volume control.*
2. *As many as 8 filter settings which can be readily changed by the operation of a switch.*
3. *Newly developed filter circuits which have proved of great value in obtaining satisfactory records in many difficult areas heretofore considered unworkable.*
4. *Extreme flexibility—four 6-trace records, two 12-trace records, or one 24-trace record may be obtained as desired.*

AGAIN WESTERN—pioneering the important advancements in geophysical prospecting—introduces a new and important development... *Multiple Recording!*

WESTERN'S new 24-Trace Seismograph Unit provides from 2 to 4 complete records per shot, obtained simultaneously with different filters. It permits a more thorough and accurate study of seismograms by placing *two or more* records on a single film. In addition, it speeds up operations in the field and makes important savings in explosives.

This multi-record innovation ranks in importance with the far-reaching advancement of the multi-string camera, which replaced single string types and opened up extensive new opportunities in exploration technique.

In the new 24-Trace Unit, WESTERN brings oil operators *another* important addition to its modern, complete and dependable geophysical service. May we have the opportunity of presenting complete details?

Western GEOPHYSICAL COMPANY

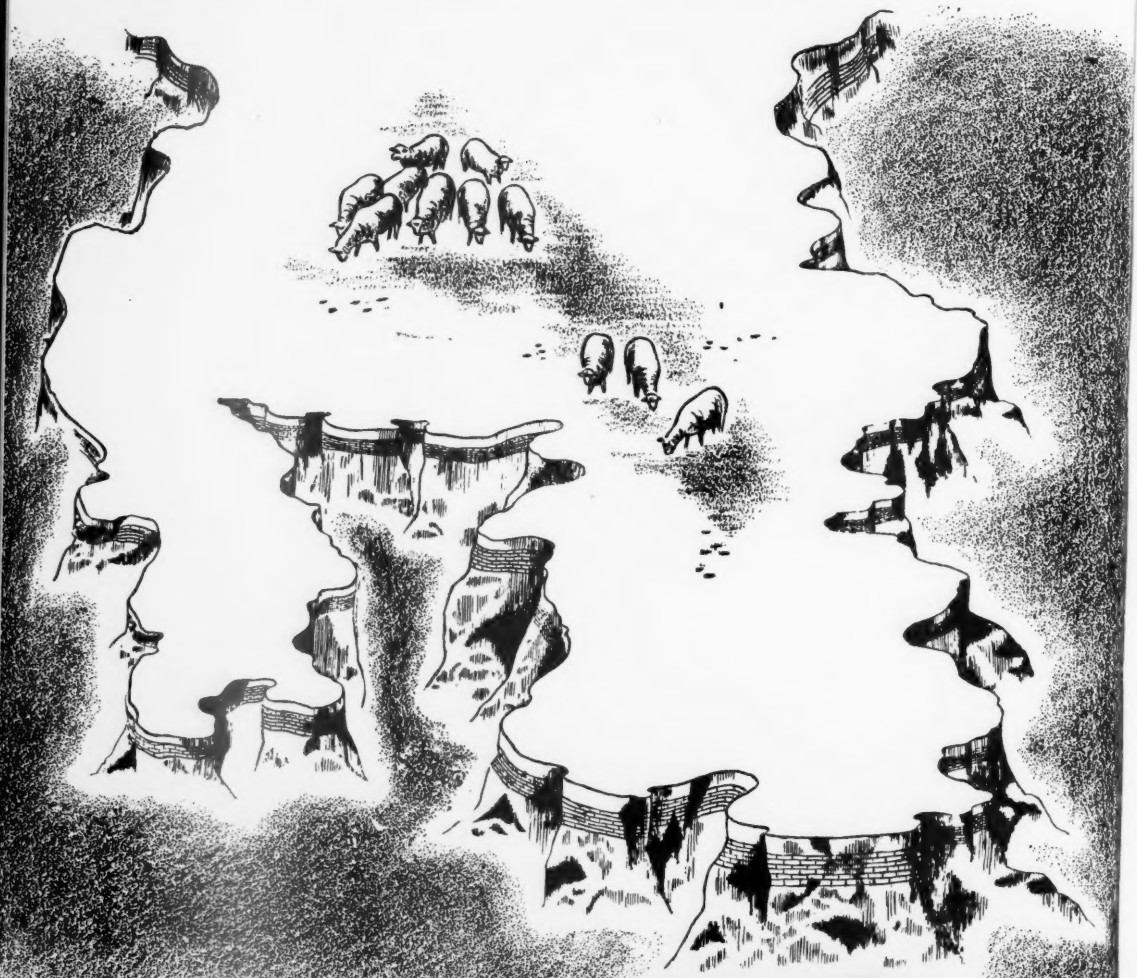
HENRY SALVATORI, PRESIDENT

EDISON BLDG., LOS ANGELES, CALIF. ★ PHILCADE BLDG., TULSA, OKLA. ★ ESPERSON BLDG., HOUSTON, TEXAS

CABLE ADDRESS: WESGECO

Edwards Plateau

THE NATIONAL GEOPHYSICAL COMPANY IS MAPPING ORDOVICIAN STRUCTURE THROUGHOUT THIS REGION



The thick surface formation of Cretaceous Limestone (Edwards Lime) has made the Edwards Plateau a problem area for the Seismograph. In fact, most seismic surveys here have been unsuccessful. But the application of NATIONAL'S new technique—plus standout personnel and equipment—has resulted in SUCCESSFUL surveys which provide control for formations as deep as the Ordovician.

National
GEOPHYSICAL
COMPANY
DALLAS • TEXAS

PRICE LIST OF THE BULLETIN

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

Box 979, Tulsa, Oklahoma

The monthly *Bulletin* contains authoritative major articles on petroleum geology and allied subjects and minor notes, discussions, and reviews. Annual subscription, $15.00 (outside United States, $15.40). Contents of Vols. I–XX (1917–1936) are indexed in detail in the *Comprehensive Index* of all A.A.P.G. publications (1917–1936); these volumes and the Index may be consulted at Association headquarters and in many college and public libraries. Volumes and numbers remaining for sale are listed here. Educational institutions are invited to write for special prices on part or complete sets insofar as available.

BULLETINS AVAILABLE (1921–1935). See COMPREHENSIVE INDEX FOR CONTENTS

		Prices	
		Members	*Non-Members*
1921	**VOL. V, NOS. 2-6**.....(5 Nos., total price to all, $2.00).....Each	($1.00)	$1.50
1922	**VOL. VI, NOS. 3-6**.....(4 Nos., total price to all, $2.00).....Each	($1.00)	1.50
1923	**VOL. VII, NO. 1**.....Each	($1.00)	1.50
1924	**VOL. VIII, NOS. 1, 3-6**.....(5 Nos., total price to all, $3.00).....Each	($1.00)	1.50
1925	**VOL. IX, NOS. 7-9**.....Each	($1.00)	1.50
1926	**VOL. X, NOS. 4-10**.....(7 Nos., total price to all, $3.00).....Each	($1.00)	1.50
1927	**VOL. XI, NOS. 6, 8-11**.....Each	($1.00)	1.50
	Full Vol., 12 mos., cloth.....	($5.00)	6.00
1928	**VOL. XII, NOS. 7-12**.....Each	($1.00)	1.50
	Full Vol., 12 mos., cloth.....	($5.00)	6.00
1929	**VOL. XIII, NOS. 1-12**.....Each	($1.00)	1.50
	Full Vol., 12 mos., cloth, or paper covers.....	($5.00)	6.00
1930	**VOL. XIV, NOS. 1-12**.....Each	($1.00)	1.50
	Full Vol., 12 mos., cloth, or paper covers.....	($5.00)	6.00
1931	**VOL. XV, NOS. 1-12**.....Each	($1.00)	1.50
	Full Vol., 12 mos., cloth, or paper covers.....	($5.00)	6.00
1932	**VOL. XVI, NOS. 1-5, 7-12**.....Each	($1.00)	1.50
1933	**VOL. XVII, NOS. 1-3**.....Each	($1.00)	1.50
1934	**VOL. XVIII, NOS. 8-12**.....Each	($1.00)	1.50
1935	**VOL. XIX, NOS. 4-7, 9-12**.....Each	($1.00)	1.50
1936	**VOL. XX, NOS. 10, 11**.....Each	($1.00)	1.50

BULLETINS AVAILABLE (1937–1941) SINCE PUBLICATION OF COMPREHENSIVE INDEX CONTENTS INDEXED IN EACH DECEMBER NUMBER

Following prices in parentheses apply to members and associates. Clothbound, whole-volume member prices apply only to members and associates who paid dues for the years quoted.

1937 **VOL. XXI.**—1,641 pp. 12 Nos. Paper. Each.....($1.00) 1.50

NO. 9—140 pp. GENERAL: Sedimentation in barred basins; barometric surveying; geothermal gradient. IOWA, MISSOURI: Burlington limestone. POLAND: Stratigraphic comparison of crude oils.

NO. 10—136 pp. CALIFORNIA: Santa Lucia Range and Salinas Valley; Pinnacles National Monument; Knoxville Mesozoic series. GENERAL: Rocky Mountains; sand analyses; X-ray crystal analysis. LOUISIANA: residues in rock salt.

NO. 11—134 pp. ARKANSAS: Pennsylvanian. GENERAL: Evaluation of petroleum index of refraction; colorimetric determination of oil open-space replacements. KANSAS and OKLAHOMA: Source beds. RUSSIA: Urals. TEXAS: Laredo.

NO. 12—129 pp. ARABIA: "Black Sea" conditions in Arabian Sea. KANSAS: Permian. NEW YORK: Oriskany. OKLAHOMA: Permian. PENNSYLVANIA: Oriskany. TEXAS: Sand Hills, Crane Co.

1938 **VOL. XXII.**—1,746 pp. 12 Nos. Paper. Each.....($1.00) 1.50

WHOLE VOLUME: Bound in two parts. Cloth.....($4.00) 17.00

NO. 1—128 pp. EAST INDIES: Geology. ILLINOIS: Discoveries. KANSAS; Conference. MONTANA: Dry Creek and Golden, Carbon Co. NEW YORK: Medina and Trenton. OHIO: Monongahela-Dunkard, Washington Co. TEXAS: Lavaca Co.

NO. 2—112 pp. CALIFORNIA: Santa Monica Bay. GENERAL: Repressuring; graptolites. LOUISIANA: Aragonite in salt-dome cap rocks. MICHIGAN: Mississippian gas sands. TEXAS: Aragonite. WEST VIRGINIA: Oriskany series.

NO. 3—152 pp. ALABAMA: Cockfield and Gosport. GENERAL: Bighorn-Yellowstone Valley. KENTUCKY: Meade, Hardin, and Breckinridge Cos. LOUISIANA: Tepetate. MISSISSIPPI: Cockfield, Gosport. PENNSYLVANIA: Oriskany.

NO. 4—124 pp. GENERAL: Appalachian field history; bibliography of structure maps and sections of oil states; folds in three dimensions. MICHIGAN: Oil and gas.

NO. 5—116 pp. GENERAL: Future of geologist; Oriskany sandstone petrology; geological limitations to oil law. NEW MEXICO: New section of Trinity age.

NO. 7—164 pp. FLORIDA: Possibilities, GEORGIA: Coastal Plain. GENERAL: Atlantic Coastal Plain; accumulation; differential settling. MISSISSIPPI: Scanlan, Midway, salt dome, Lamar Co. MISSOURI: Cherokee formation. NEW JERSEY: Possibilities. OKLAHOMA: Ouachita Mountains. TEXAS: Permian basin.

NO. 9—172 pp. ARABIA: Red Sea. CANADA: McMurray. GENERAL: Oil reservoirs; geology 100 years ago; wildcats; secondary tilt; porosity; permeability; index determination. LOUISIANA: Shreveport. TEXAS: Refugio, Segno, Cleveland pools. VENEZUELA: Central part. WEST VIRGINIA: Gas in Appalachians.

NO. 10—168 pp. GENERAL: Spacing. KENTUCKY: Irvine; "Corniferous" oil. LOUISIANA: Darrow dome. TEXAS: Barrila-Davis Mts. UTAH: Great Salt Lake.

NO. 11—156 pp. GENERAL: East-central U. S. KANSAS: "Mississippi lime." LOUISIANA: Carterville-Sarepta, Shongaloo; Sugar Creek; Cotton Valley. OKLAHOMA: Jesse, Olympic pools. TEXAS: Navarro Crossing; Cedar Point; Friendswood.

1939 VOL. XXIII.—1,922 pp. 12 Nos. Paper. Each.....($1.00) 1.50
WHOLE VOLUME: Bound in two parts. Cloth.....($4.00) 17.00

NO. 1—120 pp. CALIFORNIA: Reef Ridge shale; Santa Maria Valley field. NEBRASKA: Agate anticline. UTAH: "Park City" beds, Uinta Mts.

NO. 2—160 pp. LOUISIANA: Vicksburg Oligocene fauna. OKLAHOMA: Keokuk pool. TEXAS: Coastal Plain, Harris Co.; heaving shale. UTAH: Washington Co.

NO. 3—180 pp. LOUISIANA: Lisbon field. OKLAHOMA: Osage subseries. TEXAS: McFadden Beach salt dome.

NO. 4—164 pp. CALIFORNIA: Ridge Basin. LOUISIANA: Barataria Bay sediments. MISSOURI: Bainbridge formation. MONTANA: Baker-Glendive anticline. OKLAHOMA: Verden shoestring sand. TEXAS: Orange field; Oligocene salt erosion, Gulf Coast. U.S.S.R.: Salt domes. WYOMING: Wind River Canyon.

NO. 5—140 pp. GENERAL: Two tilts. KANSAS: Greenwich pool. OKLAHOMA: Dora pool. PERU: Agua Caliente anticline. TEXAS: Travis Peak formation; Fairbanks and Satsuma fields. TURKEY: Southern.

NO. 6—218 pp. REVIEW OF DEVELOPMENTS.

NO. 7—180 pp. GENERAL: Rock units. KANSAS: Hugoton gas field. OKLAHOMA: Wichita Mts., Arbuckle asphaltic material. TEXAS: Panhandle gas field; Carlos structure and Ferguson Crossing dome, Grimes and Brazos Cos.

NO. 8—124 pp. ARKANSAS: Basilosaurus. CALIFORNIA: Potrero Hills gas. GENERAL: Rocky Mtns.; black shale. KANSAS: Loess. LOUISIANA: Stream patterns. SOUTH DAKOTA: Pennington County. TEXAS: Ben Bolt and Magnolia City fields, Jim Wells Co.; Muralla field, Duval Co. VENEZUELA: Trinidad.

No. 9—148 pp. GENERAL: Isostatic layer; electrical well logging; Gulf Coast datum planes. ILLINOIS, INDIANA, KENTUCKY: Correlation of minable coals; Salem field, Marion Co. MISSISSIPPI: Jackson Eocene, Greenville. TEXAS: Proration.

NO. 10—164 pp. ALABAMA: Citronelle formation. CALIFORNIA: Wasco field, Kern Co. GENERAL: Microfilm; Oligocene-Miocene. ILLINOIS: Basin fields; Pennsylvanian; Cambrian inlier. NEW MEXICO: Salado formation, Permian basin. TEXAS: Goldsmith field, Ector Co.; Salado formation. WYOMING: Wind River Canyon.

NO. 11—148 pp. FLORIDA: Paleozoic? Everglades deep test. GENERAL: South Atlantic sediments; North American Permian; marine and non-marine sediments. NEBRASKA: Permian subsurface. NEW MEXICO: Castile salt, potash, anhydrite. TEXAS: Gulf Coast section; Amelia field, Jefferson Co.; Permian subsurface.

NO. 12—172 pp. GENERAL: Rotary drilling time; Cincinnati arch; European journals and war. KANSAS: Permian redbeds. KENTUCKY: St. Peter problem; McClosky productive areas. LOUISIANA: Starks field, Calcasieu Parish.

1940 VOL. XXIV.—2,232 pp. 12 Nos. Paper. Each.....($1.00) 1.50
WHOLE VOLUME: Bound in two parts. Cloth.....($4.00) 17.00

NO. 1—208 pp. WEST TEXAS-NEW MEXICO SYMPOSIUM: Pre-Permian.

NO. 2—200 pp. GENERAL: Permian and Carboniferous; economic aspects of petroleum industry; sedimentation; geophysical interpretation; Frio formation, Gulf Coast. ILLINOIS: Chester and Iowa series. SUMATRA: Oeloe Aer fault zone.

NO. 3—208 pp. GENERAL: Gulf Coast Miocene; barium in Appalachian brines. LOUISIANA: Miocene; interior salt domes. OHIO: Secondary recovery. OKLAHOMA: Morrow group, Adair Co. TEXAS: Apco structure, Pecos Co.: Sejita structure, Duval Co.

NO. 4—148 pp. ARKANSAS: Dorcheat pool, Columbia Co. AUSTRALIA: Permian heavy minerals. CALIFORNIA: Whittier Quadrangle; Kettleman Hills; Paloma field, Kern Co. COLORADO: Permian. LOUISIANA: Sparta-Wilcox. MINNESOTA; Pre-Cambrian and Cambrian. OHIO: Paleozoic and pre-Cambrian, Delaware Co. OKLAHOMA: Osage, Washington, Nowata Cos. deepest well, Washita Co. TEXAS: Lissie and Beaumont formations, Gulf Coast; Sparta-Wilcox; shoreline, Brazoria Co.

NO. 5—188 pp. GENERAL: Mississippian, Eastern Interior; geochemical exploration.

NO. 6—204 pp. RECENT DEVELOPMENTS.

NO. 7—196 pp. CALIFORNIA: Rio Bravo field, Strand field, Kern Co. TEXAS: Cretaceous ammonoids. WYOMING: Oil-field waters.

NO. 8—176 pp. GENERAL: Exploration methods; young graduates and field experience; source of hydrogen; underground gas storage. IOWA: Wildcat well, Union Co. TEXAS: Henderson pool, Clay Co.; K.M.A. field, Wichita Co.

NO. 9—176 pp. CANADA: Turner Valley Paleozoic limestone. CALIFORNIA: Bakersfield Eocene coal. COLOMBIA: Jurassic-Cretaceous. GENERAL: Radioactivity of sedimentary rocks; GULF COAST: Cook Mountain formation. NEW MEXICO: Caballos novaculite. TENNESSEE: Lower Ordovician sand zones (St. Peter). VENEZUELA: Jurassic-Cretaceous. WEST INDIES: Paleogene of Barbados.

NO. 10—160 pp. CALIFORNIA: 20 years of petroleum geology; Eocene Yokut sandstone near Coalinga. GENERAL: Applied paleontology. KANSAS: Gas pools, Hugoton field porosity, permeability. TEXAS: Saxet oil and gas field, Nueces Co.; Rogers pool and Bonita discovery, Montague Co.; Aspermont pool, Stonewall Co.

NO. 11—204 pp. CALIFORNIA: San Joaquin Valley Eocene foraminiferal correlation. GENERAL: Carbohydrates in formation of oil and coal; unconformities and accumulation. LOUISIANA: Downdip Wilcox Eocene; Neale field, Beauregard Parish. MICHIGAN: Buckeye field, Gladwin Co. MISSISSIPPI: Surface. OKLAHOMA: Ramsey pool, Payne Co.; Billings field, Noble Co., and isostasy. TEXAS: Downship Wilcox Eocene; Pittsburg field, Camp Co. WEST VIRGINIA: Devonian.

NO. 12—164 pp. CALIFORNIA: Miocene fishes, Torrance field. GENERAL: Water cones and sheaths; Permian crude oil. LOUISIANA: Gulf Coast heavy-mineral zones. MICHIGAN: Isopachous studies, Ellsworth-Traverse limestones. OKLAHOMA: Structural interpretation, gravity anomalies. TEXAS: Gulf Coast heavy-mineral zones; Hoffman field, Duval Co.; Jones Co. discovery. TRINIDAD: Los Bajos fault.

1941 VOL. XXV.—12 Nos. Paper. Each.....($1.00) 1.50

WHOLE VOLUME: Bound in two parts. Cloth.....($4.00) 17.00

NO. 1—192 pp. GENERAL: Reserves. IOWA, MISSOURI: Upper Des Moines, lower Missouri series. NEW MEXICO: San Andres group; sodium sulphate. OKLAHOMA: Southern tectonic provinces. PENNSYLVANIA: Devonian. Mississippian inliers. TEXAS: San Andres; Edna gas field, Jackson Co. WYOMING: River Mtns.

NO. 2—160 pp. CALIFORNIA: Caliente Range Miocene. EAST INDIES: Abyssal deposits. FLORIDA: Deep well, Okaloosa Co. GENERAL: Insoluble residues. LOUISIANA: Barataria field, Jefferson Parish. OKLAHOMA: Pre-Cambrian zeolite-opal sediments, Wichita Mtns. TEXAS: LaRosa field, Refugio Co.

NO. 3—209 pp. APPALACHIANS: Structure. AUSTRALIA: Upper Paleozoic. GENERAL: International oil. MISSISSIPPI: Newman salt dome, Warren Co.; Tatum salt dome, Lamar Co. TEXAS: Shipley field, Ward Co.; Coleman pool, Archer Co. WYOMING: Permian correlation.

NO. 4—220 pp. GENERAL: Gun-perforator samples. GULF COAST: Crude oils; Midway fauna; correlation chart; minerals in salt-dome cap rocks. KENTUCKY: Devonian. LOUISIANA: Midway localities; Olla field, La Salle Parish. MICHIGAN: Lower Mississippian; Antrim-Ellsworth-Coldwater shale. OKLAHOMA: Simpson group, Arbuckle and Wichita Mtns. TEXAS: North Cowden field, Ector Co.; Page field, Schleicher Co.; Navarro group fauna.

NO. 5—216 pp. APPALACHIANS: Geosyncline. GENERAL: Fresh-water lake sediments; acidizing oil reservoirs of sand; sedimentology. ILLINOIS: Chester of Illinois basin. TEXAS: Hawkins field, Wood Co. WYOMING: Freezeout Mountain-Bald Mountain area, Carbon Co.

NO. 6—204 pp. RECENT DEVELOPMENTS.

NO. 7—232 pp. CALIFORNIA: Temblor Range faulting; San Joaquin Valley seismic velocities. GENERAL: Petroleum geologists in national defense; micropaleontology; future of geophysics; petroleum and war; fifth dimension in oil industry; natural gas

and defense; Securities and Exchange Commission; volumetric methods of recovery estimation. LOUISIANA: Eola oil field, Avoyelles Parish. MISSOURI: porosity of gas fields, Jackson Co. RUSSIA: Artinskian series.

NO. 8—192 pp. FUTURE OIL PROVINCES, UNITED STATES AND CANADA. LOUISIANA: Oil-field models. OKLAHOMA: Memorial shale (Pennsylvanian). TEXAS: Initial and ultimate production, Breckenridge field, Stephens Co.

NO. 9—220 pp. COLOMBIA: Cordillera Oriental pre-Cretaceous. COLORADO: La Plata sandstone. GENERAL: Mid-Continent stratigraphy; radioactivity logging; photogeology. KANSAS, OKLAHOMA: Crude oils and stratigraphy; Oklahoma City oil pool source beds. NEW MEXICO, TEXAS: Tansill formation. WYOMING: La Barge region, Lincoln Co.; evaporite salts, Green River Basin.

NO. 10—128 pp. GENERAL: Sandstone cementing materials and oil migration; organic matter and sedimentary rock color. KANSAS: Chetopa pool oil migration, Labette Co. TEXAS: High-pressure gas problem, Wasson field, Yoakum Co.; South Cotton Lake field, Chambers Co. TURKEY: Temperature measurement in wells.

NO. 11—140 pp. CHINA: Non-marine petroleum, North Shensi; Cretaceous of Szechuan. GENERAL: Handling microfilm copy. GULF COAST: Sedimentation and accumulation. KENTUCKY: Post-Appalachian faulting. TEXAS: East White Point field Oligocene, San Patricio and Nueces Cos., Clodine field, Fort Bend Co. WYOMING: Heart Mtn.-South Fork thrusts, Park Co.

NO. 12—167 pp. GENERAL: Shadowgraphic contour maps; free-oil deposition; trace-slip faults; stratigraphic nomenclature; radioactivity well logging. NEW MEXICO: Sacramento Mtns. Mississippian.

1942 **VOL. XXVI.**—12 Nos. Paper. Each.....($1.00) 1.50

WHOLE VOLUME: Bound in two parts. Cloth.....($4.00) 17.00

NO. 1—152 pp. APPALACHIANS: Geochemistry of natural gas. GENERAL: Silurian, Mississippi Basin; subsurface unconformities; well spacing. KANSAS: McLouth field, Jefferson and Leavenworth Cos. NEW MEXICO: Salado formation, potash test, Carlsbad; Seven Rivers formation, Eddy Co. SOUTH DAKOTA: Viola graptolites, Black Hills. VENEZUELA: Ortiz and Guarumen sandstones.

NO. 2—152 pp. CALIFORNIA: Stratigraphy; Cretaceous; Del Valle field, Los Angeles Co. GENERAL: Free oil accumulation. TEXAS: Sewell-Eddleman area, Young Co.; Permian paleogeography; Eocene, Zapata Co.; Washburn field, La Salle Co.; McKee and Waddell sands, Simpson Ordovician, West Texas. UTAH: Laccolithic mountains and structural traps.

NO. 3—228 pp. CALIFORNIA: Earthquake effect, Dominquez field, Los Angeles Co. GENERAL: Member list; auditor's report. KANSAS: Patterson pool, Kearny Co. MONTANA: Madison Mississippian. NORTH DAKOTA: Stratigraphy. RUSSIA: Artinskian Permian. TEXAS: Pre-Cretaceous, Edwards Plateau; Barnhart field, Reagan Co.

NO. 4—232 pp. NEW MEXICO, TEXAS: Permian.

NO. 5—204 pp. CALIFORNIA: Sutter Buttes. COLOMBIA: Honda district. GENERAL: Pseudo-abyssal sediments; salty ground waters, Atlantic and Gulf coasts; oil-field waters bibliography; annual meeting reports. MONTANA: Cedar Creek anticline. TEXAS: Silurian graptolite, Crane Co.

NO. 6—216 pp. RECENT DEVELOPMENTS.

NO. 7—132 pp. ARKANSAS: Developments; Midway field, Lafayette Co. GENERAL: Annual meeting addresses; geological perspective; how geophysicists serve; geologists good neighbors; exploration; geology, war, peace; teaching; drilling-time logs; appraisals, oil reservoirs. GULF COAST: Tertiary microfossils. LOUISIANA: Developments.

NO. 8—124 pp. COLORADO: Gore area. GENERAL: Discovery methods. MONTANA: Oil-field water. NORTH DAKOTA: Stratigraphy. TEXAS: Ellenburger formation; Upper Pennsylvanian anhydrite.

NO. 9—136 pp. ARKANSAS: Schuler field, Union County. NEBRASKA: Cretaceous. TEXAS: Well spacing, Columbia field, Brazoria Co.

NO. 10—140 pp. CALIFORNIA: Crocker Flat, Temblor Range. COSTA RICA: Amoura shale. GENERAL: Lantern-slide copy. ILLINOIS-IOWA: Pennsylvanian. ILLINOIS-INDIANA: Chester sandstone lateral variation; New Harmony field. LOUISIANA: Morehouse late Paleozoic. NORTH, SOUTH DAKOTA: Regional. TEXAS: Payton Pool, Pecos and Ward Cos.

NO. 11— pp. GENERAL: Stratigraphical analysis and environmental reconstruction.

NO. 12— pp. GENERAL: Oligocene, southeastern U. S.; annual index.

Prices postpaid. Write for discount to colleges and public libraries.

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
Box 979, Tulsa, Oklahoma, U.S.A.

WE DEPEND ON THE REED FOR ALL OUR CORING JOBS!

REED 'BR' *Wire Line* CORE DRILL

Operators in every part of the world "Core with Confidence" with the Reed "BR" Wire Line Coring-Drilling Bit on bottom. They have learned through practice and experience that for positive results in hard or soft formations they can depend on Reed Core Drills.

COMPLETE CORING SERVICE
The REED KOR-KING CONVENTIONAL
The REED "BR" WIRE LINE
The REED STREAMLINED KOR-KING FOR SMALL HOLE DRILLING

HARD AND SOFT FORMATION HEADS INTERCHANGEABLE

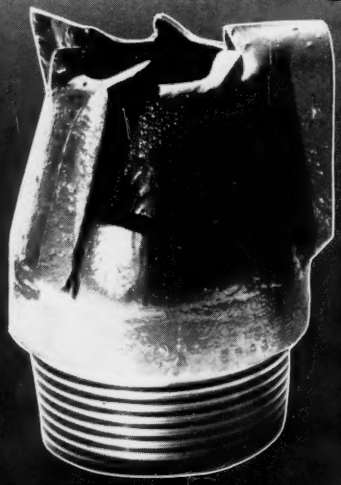
REED ROTARY DRILLING TOOLS
SPEED-ECONOMY-DURABILITY

REED ROLLER BIT COMPANY

POST OFFICE BOX 2119 HOUSTON, TEXAS

Here's why we use
HUGHES
Type 'J' CORE BITS

- Large diameter core recovered.
- Double Core Catcher---same assembly is used for both hard and soft formation coring.
- Hard and Soft Formation Cutter Heads fit the same box connection in lower end of Working Barrel --- easily interchanged for varying formations.
- Floating Core Barrel.
- Replaceable Core Barrel Tip.
- Vent for relieving pressure above core as it enters core barrel.
- Plug for keeping Core Barrel clean when running in hole.
- Ease of dressing and handling.
- Simplicity and long life of parts.
- Rugged strength of all parts for safety.



HUGHES TOOL COMPANY • HOUSTON TEXAS